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Source Category Survey
Mineral Wool Manufacturing Industry

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Research Triangle Park, NC

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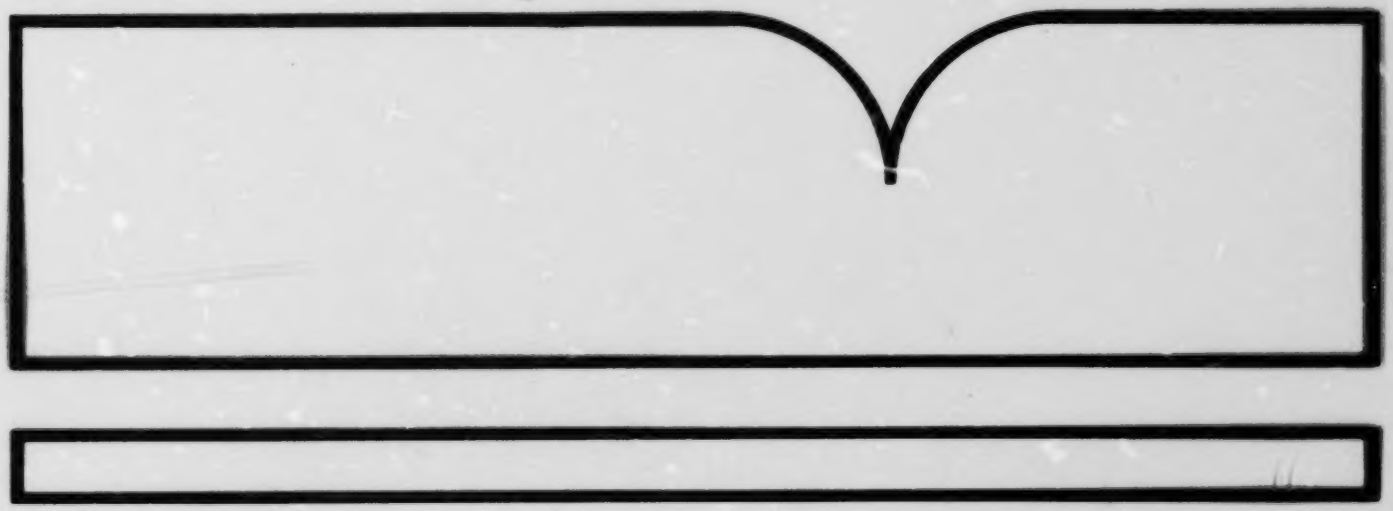

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This report contains background information which was used for determining the need for new source performance standards (NSPS) for the mineral wool manufacturing industry in accordance with Section 111 of the Clean Air Act. Air pollution emissions and growth trends of the mineral wool industry are examined. Manufacturing processes, control strategies, and state and local air pollution regulations are discussed. The impact of a potential NSPS on particulate and carbon monoxide emissions is calculated.

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Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
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1. SUMMARY

The term "mineral wool" can be used to describe any fibrous glassy substance made from minerals or mineral products. For the purpose of this study, mineral wool has been defined to include only those fibers made primarily from natural rock or metallurgical slag. Mineral wool is widely used as a structural and industrial insulation and in other products where the fiber is added to impart structural strength or fire resistance.

The number of mineral wool plants peaked at between 80 and 90 in the 1950's and then declined as fibrous glass wool penetrated the insulation market. There are about 26 mineral wool plants currently operating in the United States. These plants are typically located near a source of metallurgical slag with concentrations of plants being in Indiana, Alabama, Pennsylvania, and Texas. The remaining plants are located in 10 other States.

During the years 1972 to 1976, mineral wool insulation shipments were estimated to be about 600 million pounds per year, growing at an annual rate of less than 2 percent. This compares to an annual growth rate of 17 percent for fibrous glass insulation during the 1960 to 1974 period. Total mineral wool insulation sales were approximately 80 to 100 million dollars in 1976, with the largest manufacturer having sales of 35

to 37 million dollars. Sales of mineral wool insulation have grown since the early 1960's at an annual rate of 3 percent in constant dollars.

The demand for mineral wool has historically followed the general economic cycle since the majority of insulation materials have been used in the construction of new housing. It was anticipated that the 1977 income tax credit for energy conservation expenditures on existing homes would greatly increase the demand for insulation, but this retrofit market has not developed and mineral wool manufacturers are currently operating at about 60 percent of capacity. If an increase in sales were to occur, existing manufacturing capabilities of the insulation industry should be sufficient to meet any foreseeable demand.

Despite existing insulation production capacity and lack of increased demand, the capacity equivalent of one new mineral wool plant could be built in the next 5 years in an area of the country where it could compete for the existing insulation market.

Mineral wool is manufactured by melting rock and slag in a cupola using coke as fuel. The molten minerals are fiberized on a spinning rotor using a high velocity stream of air or steam to assist in fiber attenuation. An oil or binding agent is applied to the fiber before it is collected on a wire mesh conveyor in an area known as the blowchamber. Mineral wool containing the binder is cured in an oven, cut into batts, and usually covered with a vapor barrier of treated paper or foil. For loose wool products, no binding agent is applied and the curing oven is eliminated.

The major sources of emissions from the manufacturing of mineral wool are the cupolas, blowchambers, and curing ovens. A typical mineral

wool plant has two parallel production lines, a batt line and a wool line. The batt line consists of a cupola, blowchamber, and curing oven. The wool line has only a cupola and a blowchamber.

The most significant emission source in the process is the cupola, with approximately 3600 Mg/year (3960 Tons/year) of carbon monoxide (CO) being emitted from a typical plant. A CO control system is currently in operation at only one United States plant, and it is estimated that a 98 percent control efficiency could be achieved with controlled emissions of 180 Mg/year. Uncontrolled particulate emissions from the cupolas at a typical plant are about 366 Mg/year (403 Tons/year), but actual emissions would be controlled to approximately 54 Mg/year (59 Tons/year) to comply with the typical SIP. Baghouses are applied to two-thirds of the cupolas in operation, although cyclones, scrubbers, and ESP's are also used to control cupola particulate emissions. Particulate emissions from the cupolas at a typical plant could be reduced to 10 Mg/year (11 Tons/year) if baghouse performance equivalent to the average for baghouse test results reported in this study is assumed.

Mineral wool blowchambers are a significant source of particulates and are controlled by low energy wet scrubbers at about half the plants. Lint cages are the next most common control device in operation. Emissions from the blowchambers at a plant controlled to meet a typical SIP would be about 39 Mg/year (43 Tons/year). Two fabric filters are reportedly in use on blowchamber exhausts, but no test results could be obtained during this study. Assuming a fabric filter could limit blowchamber particulate emissions to 23 mg/scm (0.01 gr/scf), then blowchamber emissions from a typical plant could be reduced to 14 Mg/year (15 Tons/year).

The curing oven is a smaller source of particulate emissions than the cupola and blowchamber. Uncontrolled particulate emissions from the typical curing oven are about 14 Mg/year (15 Tons/year). Approximately half the plants for which data were reported use afterburners to control particulate and volatile organic compound (VOC) emissions from curing ovens. A test indicates that a 50 percent reduction can be achieved using a direct-flame afterburner. A cooling section follows the over where air at ambient temperatures is forced through the cured wool.

Nationwide emissions of primary pollutants produced by the mineral wool manufacturing industry, operated at full capacity and controlled to meet the SIP's, are estimated below:

Process Source	Particulates Mg/year	(Tons/year)	Carbon Monoxide Mg/year	(Tons/year)
Cupolas	1,450	(1,600)	95,600	(105,300)
Blowchambers	1,040	(1,150)		
Curing Ovens	270	(290)		
Cooler	190	(210)		
Totals	2,950	(3,250)	95,600	(105,300)

There are other pollutants emitted from the process. However, the only pollutant generally controlled by the SIP's is particulate matter. A detailed emission inventory is contained in Table 5-10.

States typically regulate mineral wool manufacturing under general process emission regulations. The most common formula for determining allowable particulate emissions is $E = 3.59p^{0.62}$ where E is the allowable emissions in lbs/hour and p is the process weight rate in tons/hour.

There are EPA reference methods for evaluation of several pollutants emitted by mineral wool processes; a list of methods that may be applied to mineral wool manufacturing is contained in Chapter 7.

It is not recommended that an NSPS be developed for the mineral wool manufacturing industry at this time due to the following factors:

* The mineral wool industry is currently operating at about 60 percent of capacity. Existing production capacity is sufficient to meet increased demand even if the insulation market were greatly stimulated.

* Growth of the industry is considered unlikely. Construction of one new plant in the next 5 years is possible, but expansion by more than one plant is considered to be improbable at this time.

* The emission reduction potential of an NSPS for particulates is approximately 72 Mg/year (80 Tons/year) if cupola, blowchamber, and curing oven particulate emissions from one new plant were controlled by NSPS. The emission reduction potential for cupola CO emissions is estimated to be 3,420 Mg/year.

* Existing State regulations control particulate emissions from the cupola and blowchamber so that the maximum impact on ambient air quality is estimated to be less than 3 percent of the 24-hour national primary ambient air quality standard and less than 2 percent of the annual national primary ambient air quality standard. The maximum estimated carbon monoxide concentration for uncontrolled cupolas was also estimated to be less than 5 percent of the CO 1-hour national primary ambient air quality standard and less than 10 percent of the 8-hour national primary ambient air quality standard.

2. INTRODUCTION

Mineral wool is a widely used structural and industrial insulation material which is manufactured primarily from natural rock and metallurgical slag. Although sometimes considered to be mineral wool, fibrous glass wool was excluded from this survey.

In a typical process, slag and rock are melted in a cupola using coke as fuel. The molten minerals are drained from the furnace and dropped on a spinning rotor to fiberize the material. Using fans to create a downdraft, the mineral fiber is then collected on a wire mesh conveyor in an area known as the blowchamber. The wool may then be granulated and packaged for shipment or conveyed to an oven for curing of a binder which adds structural rigidity to the insulation. The cured fiber blanket may then be cut into batts and covered with a vapor barrier of treated paper or foil.

Those emission sources primarily examined during this study were the exhausts from mineral wool cupolas, blowchambers, and curing ovens. Emissions from other mineral wool manufacturing processes were judged not to be significant enough to be considered for development of new source performance standards.

The authority to promulgate standards of performance for new sources is derived from Section 111 of the Clean Air Act. Under the Act, the Administrator of the United States Environmental Protection Agency is

directed to establish standards relating to the emission of air pollutants and is accorded the following powers:

1. Identify those categories of stationary emission sources that contribute significantly to air pollution, the emission of which could be reasonably anticipated to endanger the public health and welfare.

2. Distinguish among classes, types, and sizes within categories of new sources for the purpose of establishing such standards.

3. Establish standards of performance for stationary sources which reflect the degree of emission reduction achievable through application of the best system of continuous emission reduction, taking into consideration the cost, energy, and environmental impacts associated with such emission reduction.

The term "stationary source" means any building, structure, facility, or installation which emits or may emit any air pollutants. A source is considered new if its construction or modification is commenced after publication of the proposed regulations. Modifications subjecting an existing source to such standards are considered to be any physical change in the source or change in methods of operation which results in an increase in the amount of any air pollutant emitted. Reconstructions subjecting an existing source to these standards are considered to be any replacement of components of an existing facility the fixed capital cost of which exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility. The conditions under which a modified or reconstructed source is subject to an NSPS are defined in Title 40, Code of Federal Regulations, Part 60.

The Clean Air Act amendments of 1977 require promulgation of the new source standards on a greatly accelerated schedule. As part of the schedule, this source category survey was performed to determine if development of new source performance standards for the mineral wool manufacturing industry was justified and to identify what processes and pollutants, if any, should be subject to regulation. In determining priorities for promulgating new source standards, the following are considered:

1. The quantity of air pollutant emissions which each source category will emit or will be designed to emit.

2. The extent to which each pollutant may reasonably be anticipated to endanger public health or welfare.

3. The mobility and competitive nature of each source category and the consequent need for nationally applicable new source performance standards.

Information necessary for development of the mineral wool manufacturing source category survey was gathered through the following activities:

1. Collection of process and emission data from literature searches and contacts with State and local air pollution control agencies.

2. Visiting several mineral wool plants to develop an understanding of manufacturing processes, and to collect data on operating air pollution control equipment.

3. Contacting representatives of industry, trade associations, and government agencies to gather information on current mineral wool production and projected industry expansion.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

The number of mineral wool plants has decreased from more than 80 in the 1950's to about 26 plants in 1979. This decline in the number of plants is primarily due to the penetration of the insulation market by fibrous glass and cellulosic materials.

The oil embargo of 1973 - 1974 and the following OPEC price escalations resulted in increased interest in energy conservation in new and existing structures. As a result of increased consumer demand, mineral insulation (fibrous glass and mineral wool) industry doubled production capacity during the 1970's in anticipation of further increases in the insulation market. Expectations of greatly increased demand were heightened by the 1977 income tax credit for energy conservation expenditures on existing homes and announcement of Minimum Property Standards by the Department of Housing and Urban Development, which specify thermal insulation efficiencies for new housing.

Large increases in demand for insulation productions which were anticipated a few years ago have not developed. Mineral wool production capacity which was added in the last several years has not been utilized, and the mineral wool industry is currently operating at about 60 percent of capacity. If the insulation market were greatly stimulated, existing manufacturing capacity should be sufficient to supply any foreseeable

demand. In 1977, it was estimated that the then existing production capacity and committed capacity expansion could supply sufficient materials to insulate the 25.5 million housing units needing insulation improvement by 1981 if the activity was restricted to attics only, or by 1983 if upgrading included sidewalls as well as attics. If only single-family dwellings were retrofitted, the thermal improvement could be completed in less time.

Two new mineral wool plants have begun operation in the last 2 years. One plant is currently under construction and is scheduled to begin operation in 1980. Two of these plants were built with only a single production line; the other plant was constructed with two production lines but one of those lines has never been put into operation. It has been estimated that at least 2 years would be required to bring a new mineral wool plant on line.[1] These most recently constructed plants were apparently planned at the time when increased demand for insulation was anticipated and existing plants were operating near capacity.

In the past 2 years, at least 2 mineral wool plants have closed. One plant was operated by the U.S. Gypsum Company and the other by the Johns-Manville Corporation. The Johns-Manville plant produced only bulk mineral wool fiber which was used in the manufacturing of ceiling tile. Before closing their operations, Johns-Manville performed a detailed market survey and determined that there was no national demand for bulk mineral wool.[2]

Despite the existing lack of increased demand for insulation, it is still possible that the mineral wool industry will add the capacity equivalent of one new plant in the next 5 years. Both raw materials

and finished products are bulky, making it economically attractive for a plant to locate either near a source of raw materials or product demand. A new mineral wool plant could compete for the existing insulation market in some areas of the country where regional competition was not great. Major modifications or reconstructions to existing plants are not considered likely to occur in significant numbers due to current market conditions and existing production capacity.

Data were obtained for both uncontrolled and controlled emissions from the mineral wool process from several State/local control agencies. Data summaries were utilized from these test reports to determine pollutant concentrations from control devices, uncontrolled and controlled emission factors, and amounts of pollutants emitted from typical mineral wool processes. There are six particulate emission tests for baghouse control of cupolas, one particulate test for an ESP on a curing oven, and one test of CO emissions from a cupola CO control system which would require review in detail if a study to develop an NSPS were to be initiated. Detailed test data would have to be obtained from the control agencies and/or plants before such a review could be accomplished.

There are EPA reference methods for evaluation of some pollutants emitted by mineral wool processes. These reference methods are listed in Chapter 7 of this report.

The emission reduction achievable with an NSPS, impact of pollutant(s) on public health or welfare, and the ability of the source to locate in State(s) with less stringent air pollution standards than other States were the major factors considered before making a recommendation whether an NSPS should or should not be developed for mineral

wool manufacturing. A description of how these factors were analyzed is outlined in the following discussion.

The most significant emission source in the mineral wool process is the cupola. The largest emission of a pollutant occurs from the cupola at an approximate uncontrolled rate of 3,600 Mg/year of carbon monoxide. A CO control system is operating at 1 United States plant, and a recent test has indicated a control efficiency as high as 98 percent. If a more conservative control efficiency of 95 percent is assumed, carbon monoxide emissions could be reduced to 180 Mg/year, a reduction equivalent to about 3,420 Mg/year for each new plant constructed. The next greatest amount of an uncontrolled pollutant is the particulate emitted from the cupolas which amounts to about 366 Mg/year, but the actual emissions would be controlled to approximately 54 Mg/year to comply with the typical SIP. Baghouses are applied to two-thirds of the cupolas although cyclones (alone or in combination with other devices), wet scrubbers, and an ESP are also used to control cupola particulate emissions. If baghouse performance equivalent to the average of the controlled emission factor contained in Table 6-2 is used as a basis, cupola particulate emissions from a typical plant could be reduced to about 10 Mg/year, or a decrease of approximately 44 Mg/year for each new plant constructed. There are emissions of sulfur oxides, hydrogen sulfide, and nitrogen oxides from the cupola, but no control technology has been demonstrated for these pollutants at any United States plants.

The mineral wool blowchamber is a significant particulate source, and the most commonly applied control devices are low energy scrubbers which are used at about half the plants. Lint cages are the next most

commonly used control device with a few cyclones reportedly in use. The emissions from blowchambers would be 39 Mg/year at a mineral wool plant complying with the SIP. Two fabric filters are reported to be used to control blowchamber particulate emissions although no test results could be obtained during this study for this application. If it is assumed that fabric filters can reduce blowchamber emissions to 0.011 gr/scf (this degree of control is reported in Table 6-3 for a wet scrubber and ESP combination and, for the purposes of this analysis, it was assumed that fabric filtration could achieve equivalent results), then blowchamber emissions would be reduced to about 14 Mg/year, a reduction of about 25 Mg/year for each new plant constructed. The blowchambers are also sources of some volatile organic compounds (VOC) and two afterburners are reported to be used to control blowchamber emissions. However, the large volume of air typically exhausted from blowchambers would probably make operating costs prohibitive for afterburner control of blowchamber exhausts at most plants, and no emission reduction benefit for blowchamber VOC emissions was considered for that reason.

The curing oven is a smaller source of particulate than the cupola and blowchamber, but about half of the plants for which data were reported use afterburners to control particulate and VOC emissions from curing ovens. An emission reduction of 50 percent of uncontrolled curing oven particulate emissions was assumed based upon a test reported in AP-40 for a direct-flame afterburner controlling curing oven particulate. On this basis, it is estimated that uncontrolled particulate emissions could be reduced from 14 Mg/year to 7 Mg/year or a reduction of 3 Mg/year from the 10 Mg/year emission level of the typical SIP for each new plant construction.

The emission reduction potentially achievable by development of an NSPS was calculated assuming the construction of one new plant or equivalent within the next 5 years. Due to regional market considerations, there is a possibility that a new plant will be built even though existing production capacity far exceeds current demand. At this time, it is considered unlikely that additional growth will occur. The emission reduction achievable at the end of the 5-year period by an NSPS for carbon monoxide and particulates from cupolas and particulates from blowchambers and curing ovens is summarized below:

Emission Reductions Achievable by NSPS - Mg/year

	Particulates	CO
Cupola	44	3,420
Blowchamber	25	--
Curing Oven	3	--
Totals	72	3,420

An estimate of the impact of mineral wool manufacturing emissions on the ambient environment was evaluated by calculating maximum ground level concentrations using two simplified Gaussian dispersion models. The pollutants evaluated were carbon monoxide emissions from mineral wool cupolas and particulate emissions from cupolas and blowchambers. An uncontrolled emission rate was assumed for cupola CO emissions under the typical SIP emission standard since only one plant has a control system for cupola CO emissions while emission rates equivalent to the typical SIP were assumed for particulate emissions from the cupola and blowchamber. The maximum ambient particulate concentrations were

estimated to be less than 3 percent of the 24-hour national primary ambient air quality standard for total suspended particulate and less than 2 percent of the annual national primary ambient air quality standard for total suspended particulate from either the cupola or blowchamber complying with the typical SIP. The maximum estimated ambient CO concentration for an uncontrolled cupola was less than 5 percent of the CO 1-hour national primary ambient air quality standard and less than 10 percent of the CO 8-hour national primary ambient air quality standard.

For cupolas equipped with CO control systems, the maximum estimated 1-hour and 8-hour concentrations are less than 1 percent of the respective national primary ambient air quality standards. Plant location appears to be generally dependent upon a source of raw materials, especially slag, and market considerations. Selection of a site based upon less stringent State emission standards is not likely to be as major a consideration in site selection as would the market area to be served by a new plant.

It is not recommended that an NSPS be develcped for mineral wool manufacturing at the present time. The factors that support this recommendation are:

* The mineral wool manufacturing industry is presently operating at about 60 percent of capacity. Sufficient excess capacity exists to supply insulating materials even with strong stimulation of the market. There are at least two idle mineral wool plants which could possibly be brought into production if the insulation market improved significantly.

* Growth is considered fairly unlikely for the mineral wool industry. One plant construction in the next 5 years is a possibility, but expansion by more than one plant would have to be considered as improbable unless market conditions change drastically.

* The emission reduction potential of an NSPS for particulates is approximately 72 Mg/year if cupola, blowchamber, and curing oven emissions of one new plant are controlled with NSPS. The emission reduction potential for cupola carbon monoxide emissions is estimated to be 3,420 Mg/year.

* An estimate of maximum impact on ambient air quality indicates that existing SIP's control cupola and blowchamber particulate emissions to less than 3 percent of the 24-hour and less than 2 percent of the annual average national primary ambient air quality standards. The maximum estimated CO concentrations were found to be less than 5 percent of the 1-hour and less than 10 percent of the 8-hour national primary ambient air quality standards.

REFERENCES

1. ICF, Incorporated. Supply Response to Residential Insulation Retrofit Demand. Report to the Federal Energy Administration. Contract Number P-14-77-5430-0. Washington, D.C. June, 1977. Page 18.

2. Memorandum from L. Anderson, United States Environmental Protection Agency, to J.U. Crowder, United States Environmental Protection Agency. August 22, 1979. Trip Report to Johns-Manville mineral wool manufacturing plant, Alexandria, Indiana.

4. INDUSTRY DESCRIPTION

4.1 SOURCE CATEGORY

"Mineral wool" is a term that can be used to describe any fibrous glassy substance made from minerals (e.g., natural rock) or mineral products (e.g., slag or glass). For the purpose of this study, mineral wool has been defined to include only those fibers made from natural rock (rock wool), slag (slag wool), or a mixture of rock and slag. Thus, fibrous glass wool has been excluded.

Mineral wool consists of silicate fibers typically 4 to 7 micrometers in diameter. It is widely used as a structural and industrial insulation and in the manufacturing of other products where the fiber is added to impart structural strength or fire resistance. Uses of mineral wool include:

* "Blowing" wool or "pouring" wool that can be blown pneumatically or poured by hand into the structural spaces of buildings.

* Batts, which may be covered with a vapor barrier of paper or foil, shaped to fit between the structural members of buildings.

* Industrial and commercial products such as high density fiber felts and blankets used for insulating boilers, ovens, pipes, refrigerators, or other process equipment.

* Bulk fiber that is used as a raw material in the manufacturing of other products, such as ceiling tile, wall board, spray-on insulation, cement, and mortar.

Some crude forms of slag wool were produced as early as 1840, but it was not until late in the 19th century that mineral wool was manufactured on a modest scale. One of the first successful slag wool processes began operation in Manchester, England, around 1885, using blast furnace slag as a raw material. C.C. Hall, using naturally occurring limestone as a raw material, first manufactured rock wool about 1900 in Alexandria, Indiana. Prior to the development of Hall's rock wool process, at least one slag wool plant was in operation in the United States. Although several mineral wool plants were in operation in the early 1900's, it was not until after the first World War that mineral wool began to acquire a substantial market. By 1939, there were 25 mineral wool plants operating in the United States.[1]

The number of mineral wool plants peaked at between 80 and 90 plants in the 1950's and then declined as fibrous glass insulation penetrated the market which had previously been held by mineral wool.[2] Many of the plants which closed were small, single line facilities which have been replaced by larger, multi-line installations. Today, about 26 mineral wool plants are operating in the United States. Table 4-1 is a listing of mineral wool manufacturing facilities. One new mineral wool plant is presently under construction in Woodbridge, Virginia, and is scheduled to begin operation in 1980.

Table 4-1. Mineral Wool Manufacturers

Alabama	
Celotex	Birmingham
Rockwool Manufacturing Company	Leeds
U. S. Gypsum Company	Birmingham
California	
Rockwool Industries	Fontana
Colcrado	
Rockwool Industries	Pueblo
Illinois	
Forty Eight Insulations	Aurora
Indiana	
Celotex	Lagro
Guardian Industries	Huntington
L. C. Cassidy and Son	Wabash
Johns-Manville Corporation	Alexandria (closing 9/79)
Rockwool Industries	Alexandria
U. S. Gypsum Company	Wabash
Minnesota	
Carney Insulation	Mankato
Conwed Corporation	Red Wing
Missouri	
Eagle-Picher Corporation	Joplin
Rockwool Industries	Cameron
New Jersey	
U. S. Mineral Products	Stanhope

Table 4-1. Mineral Wool Manufacturers (Continued)

North Carolina	
Spring Hope Rockwool	Spring Hope
Ohio	
Forty Eight Insulations	Alliance
Pennsylvania	
Bethlehem Steel Corporation	Bethlehem (2 plants)
Celotex	Pittston
Tennessee	
Fiberfine	Memphis
Texas	
Mineral Wool Manufacturing	Rogers
Rockwool Industries	Belton
U. S. Gypsum Company	Corsicana
Washington	
U. S. Gypsum Company	Tacoma

When examining production and growth of the mineral wool manufacturing industry, it is important to consider the influence of the other types of thermal insulation materials which compete with mineral wool for the existing market. There are seven primary types of thermal insulation materials used in residential, commercial, and industrial structures: fibrous glass wool, mineral wool, cellulose, mineral granules, foams, insulating board, and aluminum foil. However, fibrous glass wool, mineral wool, and cellulose account for the vast majority of the value of shipments in the insulation industry.

Insulation properties of a material are measured in "R" values. "R" is a measure of resistance to conduction of heat; the higher the "R" value, the greater the resistance to heat transfer through the material.

Fibrous glass insulation has a thermal resistance of approximately R-3.2 per inch of thickness for batts and 2.2 for blowing wool. The insulation is relatively lightweight as compared to mineral wool and cellulose insulation.

While mineral wool has somewhat better high temperature insulation properties and fire prevention characteristics than fibrous glass wool, it weighs about 2.2 times more per unit volume. The thermal resistance of mineral wool insulation is about R-3.4 per inch for batts and 2.9 for blowing wool.

Cellulosic insulation can be made from newsprint, paperboard, or wood fiber, with the addition of fire retardant chemicals. Raw materials are plentiful, the technology is simple, and the capital requirements to produce the material are not high, making cellulosic

insulation less expensive than many other products. This lower cost alternative is particularly attractive to those who want to retrofit an existing structure as economically as possible. Cellulose insulation weighs about 3.5 times more per unit volume than fibrous glass, and the fire retardant properties of cellulose are not as good as glass or mineral wool.

4.2 INDUSTRY PRODUCTION

In this section, mineral wool sales and production are discussed, and future demand is projected. Also described are the current insulation market conditions and how this affects expansion of the mineral wool manufacturing industry.

4.2.1 Mineral Wool Sales and Production

Although Standard Industrial Classification (SIC) 3296 is called "mineral wool," this classification includes a variety of mineral fiber products such as mineral wool, fibrous glass wool, fiber board, and accoustical tile. The United States Department of Commerce Census of Manufacturers does not report production data specific to the mineral wool manufacturing industry as defined in this study. The Mineral Insulation Manufacturers Association considers mineral insulation to include fibrous glass wool and does not maintain current production data.

The largest United States manufacturer of mineral wool insulation was reported to have had sales of approximately $35 to $37 million in 1976, and the second largest producer had sales totalling about $20 million.[3] Total mineral wool insulation sales were on the order of $175 million per year during the 1972 to 1974 period with about 65 percent coming from sales of structural insulation and the remaining 35 percent being sales

of industrial and equipment insulation.[4] Industry sources report that total mineral wool sales were approximately $80 to $100 million in 1976.[5] According to reported market research data, sales have grown since the early 1960's at an annual rate of only 3 percent in constant dollars.[6]

During the years 1972 to 1974, mineral wool insulation shipments were estimated to be about 600 million pounds, growing at an annual rate of less than 2 per cent. This compares to an annual growth rate of 17 percent for fibrous glass insulation over the 1960 to 1974 period.[7] Although shipments of mineral wool grew slightly during the early 1970's, mineral wool has steadily lost its share of the thermal insulation market to fibrous glass and cellulose. Tables 4-2 through 4-4 show the quantity and value of insulation shipments in 1976 and the distribution of demand for insulating materials.

4.2.2 Projected Demand for Insulation

The demand for insulation has historically followed the general economic cycle since the majority of insulation materials have been used in the construction of new housing and industrial process equipment. The oil embargo of 1973 - 1974 and the following OPEC price escalations resulted in increased energy conservation measures on existing structures. Increased consumer demand, coupled with a strike at a major fibrous glass wool manufacturer, resulted in spot shortages of structural insulation during the mid-1970's. As a result of these shortages, the insulation industry committed itself to major expansions in production capabilities to meet the anticipated demand for energy conservation products. Following the severe winter of 1976 - 1977, expectations of increased demand were heightened by the 1977 income tax credit for energy

Table 4-2. Insulation Industry Shipments by Material, 1976[8]

Insulating Material	Estimated Shipments of Structural Insulating Material	
	Quantity (lbs x 10^6)	Value ($ x 10^6)
Fiber glass	1,400	470
Rock wool	400 - 500	80 - 115
Cellulose	600	65

Table 4-3. Demand for Insulation by Material[9]

	Fiber Glass	Rock Wool	Cellulose
Industrial equipment and pipes	35%	30%	10%
Building construction	65%	70%	90%
New residential	35%	25%	10%
Reinsulation/remodelling	20%	15%	75%
Commercial/industrial	10%	30%	5%

Table 4-4. Building Construction Insulation Demand[10]

	Fiber Glass	Rock Wool	Cellulose	Total
New residential construction	90%	10%	*	100%
Reinsulation and remodelling	65%	15%	20%	100%
Commercial and industrial building	65%	35%	*	100%

* Less than 0.5%

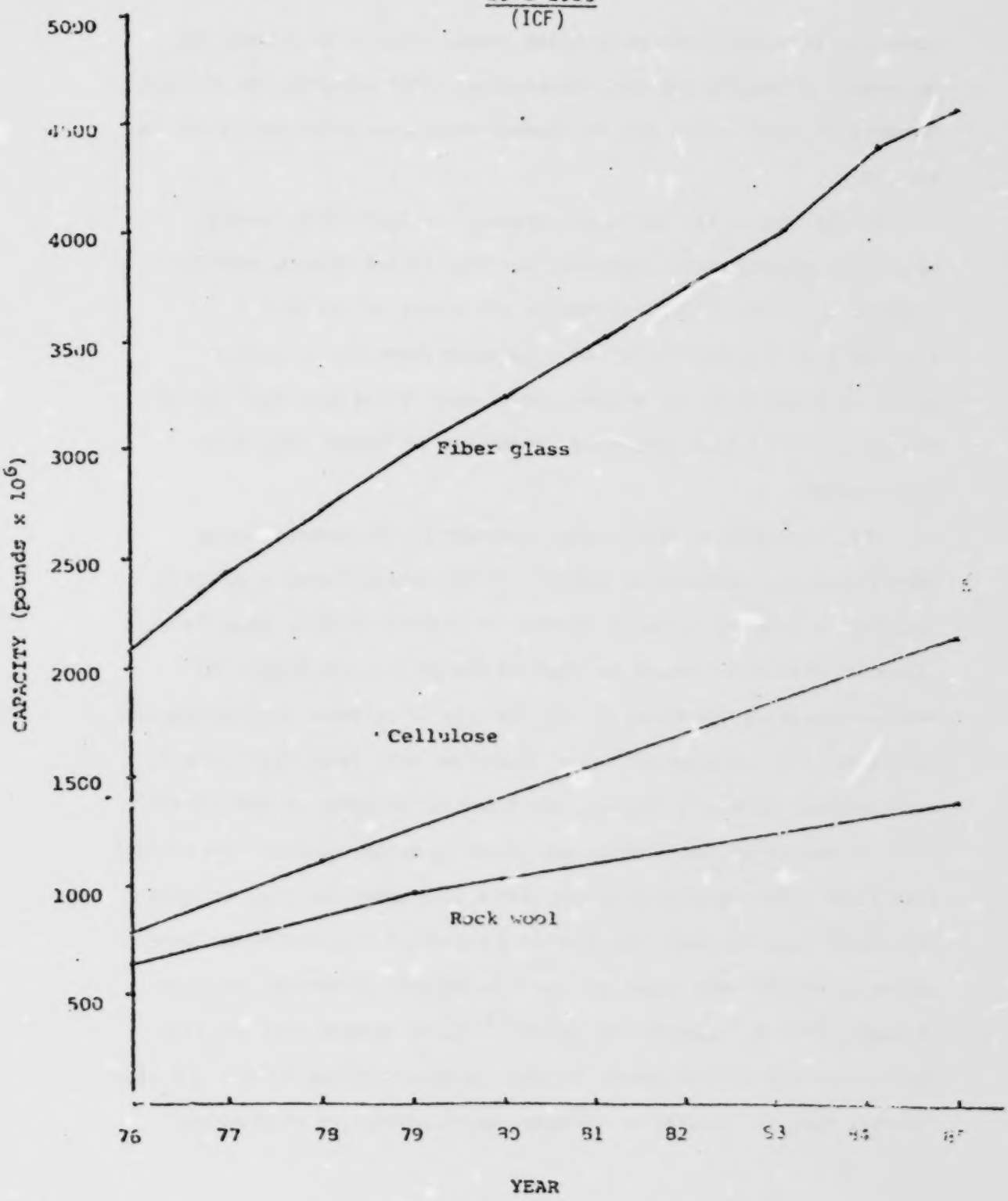
conservation expenditures on existing homes. Also at this time, the Department of Housing and Urban Development (HUD) announced the Minimum Property Standards which specify thermal insulation efficiencies for new housing.

At the time of the tax credit proposal in April 1977, several government agencies were concerned that legislative efforts could be hampered by a lack of precise data on the supply of insulation. Although existing statistical data indicated there was an adequate supply of storm doors and windows, there were little data available on the present and future production capability of thermal insulation manufacturers.

ICF, Incorporated (ICF), under contract to the Federal Energy Administration, conducted an analysis of the United States insulation industry in order to estimate current and planned industry capacity and potential insulation demand in light of the pending tax credit for energy-conserving investments. ICF had only 10 calendar days to complete this work, and conducted extensive interviews with insulation industry associations, company officials, and financial analysts in June of 1977.

ICF estimated that mineral wool capacity would increase less rapidly than fiber glass capacity over the next 4 to 7 years and that cellulosic insulation capacity would increase more rapidly.[11] According to their estimate, mineral wool capacity could increase by 10 percent per year through 1979 and 7 percent thereafter.[12] Total mineral wool capacity could total 1.3 billion pounds in 1985, as shown in Figure 4-1. ICF also reported that all insulation producers were undertaking or planning

Figure 4-1. Estimated Structural Insulation Capacity, 1976-1985 (ICF)



capacity increases in 1977 and that mineral wool manufacturers were operating near capacity at the time of the study.[13]

ICF concluded that there would appear to be no shortage of insulation capacity for retrofit purposes after 1977. At full capacity in 1977, enough insulation could be supplied to retrofit 4.6 million homes per year at "average" retrofit levels. Demand for retrofit in 1977 was variously estimated at 2 to 3 million homes without a tax credit. An additional 1 to 4 million homes could be added as a result of a tax credit.[15]

At the same time as the ICF analysis, a similar study was undertaken by the Office of Business Research and Analysis (OBRA) of the United States Department of Commerce. OBRA mailed a questionnaire to producers of insulation materials and received responses from an estimated 95 percent of the industry. The capacity figures reported include production capacity as of January 1, 1977, plus financially approved expansion plans through January 1, 1980, and proposed expansion plans with no financial commitment.[16]

Fiber Glass

Capacity:

Batts and Blankets

January 1, 1977 Million Square Feet of R-11 Equivalent	January 1, 1980 Million Square Feet of R-11 Equivalent
8,318	11,270

Loose Fiber

January 1, 1977 Million Square Feet of R-19 Equivalent	January 1, 1980 Million Square Feet of R-19 Equivalent
535	820

Cellulose Capacity:	January 1, 1977 (lbs)	January 1, 1980 (lbs)
	1,677,648,000	4,896,384,000

Mineral Wool Capacity:

Batts and Blankets

January 1, 1977 Million Square Feet of R-11 Equivalent	January 1, 1980 Million Square Feet of R-11 Equivalent
917	1,197

Loose Fiber

January 1, 1977 Million Square Feet of R-19 Equivalent	January 1, 1980 Million Square Feet of R-19 Equivalent
491	851

Based on the information obtained from the completed questionnaires and an analysis of the existing housing inventory, new construction starts and the construction materials industry, OBRA estimated that there were approximately 25.5 millon housing units in 1977 that could be improved by adding additional insulation. The then existing industry capacity and committed expansion would provide sufficient thermal insulation materials to insulate these housing units by 1981 if retrofit was restricted to attics only or by 1983 if walls as well as ceilings were upgraded.[17] Tables 4-5 and 4-6 show the housing units which could be insulated through 1982 with existing and committed capacity expansion.

There is little agreement in the industry as to the actual number of housing units that require additional insulation to meet current

Table 4-5 —Existing Capacity and Approved/Committed Capacity Expansion for Supply of Insulation Materials for One- To Four-Family Housing Units (Attic/Ceiling and Sidewall Insulation)

[Thousand Units]

	1977	1978	1979	1980	1981	1982
Housing inventory to be insulated at beginning of period	25,500	23,295	20,280	16,102	10,970	5,838
New starts (one-four family units)	e1,900	e1,900	e2,000	e2,000	e2,000	e2,000
Mobile homes	e300	e350	e400	e400	e400	e400
Number of homes that can be insulated[1]	22,555	22,819	23,529	23,750	23,750	23,750
	3484	3499	3513	3513	3513	3513
	4987	41,562	42,148	42,880	42,880	42,880
	5237	5239	5240	5240	5240	5240
	663	667	668	669	669	669
	779	779	780	780	780	780
Total	4,405	5,265	6,578	7,532	7,532	7,532
Number of homes that can be retrofitted after subtracting requirements of new housing starts	2,205	3,015	4,178	5,132	5,132	5,132
Balance of units left to be insulated	23,295	20,280	16,102	10,970	5,838	706

[1] The materials listed in the columns were combined in some instances with urea formaldehyde (UF) foam to arrive at the number of homes that could be insulated. Since UF foam is used only for sidewall insulation, the other materials were presumed to provide the corresponding attic insulation in each housing unit.

[2] fiber glass and UF foam (1977-82) [3] rock wool [4] cellulose and UF foam (1979-82) [5] aluminum multi-layered reflective foil and UF foam (1979-82) [6] perlite loose fill and UF foam (1979-82) [7] vermiculite loose fill and UF foam (1979-82)

e = estimate

Table 4-6 —Existing Capacity and Approved/Committed Capacity Expansion for Supply of Insulation Materials for One-Family Housing Units (Attic/Ceiling Insulation Only)

[Thousand Units]

	1977	1978	1979	1980
Housing inventory to be insulated at beginning of period	20,700	16,526	11,001	3,942
New starts (one-family units)	e1,400	e1,400	e1,400	e1,400
Mobile homes	e300	e350	e400	e400
Number of homes that can be insulated[1]	23,050	23,443	24,188	24,538
	3767	3791	3813	3813
	41,678	42,656	43,470	43,557
	5237	5239	5240	5240
	663	667	668	669
	779	779	780	780
Total	5,874	7,275	8,859	9,297
Number of homes that can be retrofitted after subtracting requirements of new housing starts and mobile homes	4,174	5,525	7,059	7,497
Balance of units left to be insulated	16,526	11,001	3,942	...

[1] The materials listed in the columns were combined in some instances with urea formaldehyde (UF) foam to arrive at the number of homes that could be insulated. Since UF foam is used only for sidewall insulation, the other meterials were presumed to provide the corresponding attic insulation in each housing unit.

[2] fiber glass and UF foam [3] rock wool [4] cellulose [5] aluminum multi-layered reflective foil [6] perlite loose fill [7] vermiculite loose fill

e = estimate

Source: ref. 17

thermal efficiency standards because the level of existing insulation is not known. In 1977, estimates ranged from less than 25 million to more than 40 million homes.[19] Even the 25 million estimated could be overstated if many homeowners in the more temperate regions of the country do not choose to install additional insulation. It is important to keep in mind that the ICF and Department of Commerce growth estimates were based on expectations of high demand. The purpose of these studies was to estimate the maximum possible expansion of the insulation industry in the presence of high demand and a tax credit.

4.2.3 The Current Insulation Market

Present market conditions indicate that the demand for insulation materials which was anticipated in 1977 has not developed. The tax credit as enacted allows for a credit of 15 percent of the total energy conservation expenditure; the maximum credit is $300 for each residence. Industry sources report that only 12 percent of the income tax returns for 1978 request credit for installation of any type of energy conserving products (insulation, storm doors and windows, caulking, furnace burners, etc.).[20] This includes all claims in the period from April 20, 1977, to December 31, 1978. Although the mineral insulation (mineral wool and fibrous glass) industry has expanded about 35 percent since 1977,[21] present mineral wool production is about 60 percent of capacity. Retrofit of insulation still only consumes a small portion of mineral wool production with the remainder being used in new housing and industrial applications. Apparently, the existing tax credit has not provided sufficient incentive to homeowners to retrofit at the rates previously assumed. Consumers most inclined to insulate and those most receptive to the economics of installing additional insulation have

already retrofitted their homes. The existing tax credit has not made the addition of thermal insulation economically attractive to the remaining homeowners.

4.2.4 Estimated Industry Expansion

As previously stated, the mineral wool industry is currently operating at about 60 percent of capacity. If the insulation market was to improve significantly, existing industry capacity could supply sufficient thermal insulation to meet any foreseeable demand. It was shown in Section 4.2.2 that the estimated 25.5 million housing units needing insulation improvement could be supplied with materials from existing industry capacity within 6 years, assuming new housing starts will average 2 million units annually. If new housing starts decrease due to increasing interest rates on home mortgages, each 1 percent drop in new housing starts will make enough insulation available for 50,000 additional retrofit installations.[22]

While higher energy costs may eventually result in greater retrofit activity, it is not likely that significant expansion of the mineral wool industry would occur since retrofit activity of this magnitude would be short-lived. If spot shortages of insulation materials were to occur, this demand could most quickly be met by cellulosic insulation manufacturers. Because the technology needed to produce cellulose insulation is rather simple and the capital requirements are not high, the industry is subject to easy entry. During a period of high demand in 1977, it was reported that 10 to 12 manufacturers of cellulose insulation were entering the business every month.[23] However, the demand for cellulose products could be restrained if the materials are perceived by consumers

to be less desirable because of quality problems such as fire retardancy and vermin resistance. The availability of boric acid, which is used as a fire retardant, could also constrain the expansion of cellulosic insulation production.

Despite the existing lack of increased demand for insulating materials, it is still possible that the capacity equivalent of one new mineral wool plant could be constructed in the next 5 years. Expansion by more than one plant is not considered likely at this time. Both raw materials and finished products are bulky, making it economically attractive for plants to locate either near a source of raw materials or product demand. A new plant could conceivably be built in an area of the country where regional competition was not great. Even though national production capacity for insulation far exceeds current demand, a new mineral wool plant could compete for the existing market in some areas of the United States.

Existing mineral wool plants without batt-producing capabilities could be modified to produce batts, but this is not considered likely due to current market conditions and existing production capacities. Existing plants might also add an entire production line, but due to nonutilization of present production capacity, this is not likely to occur unless demand for insulation increases significantly.

Demand for mineral wool insulation could increase if the Federal Government enacts more stringent legislation on the thermal efficiencies of new residential and commercial buildings. Reportedly, the Department of Energy will propose Building Energy Performance Standards in late 1979. These standards will be an extension of HUD's Minimum Property

Standards, and the "goals" of these standards could be met by existing insulation manufacturing capabilities.[24]

4.3 PROCESS DESCRIPTION

Today, very little pure rock wool or slag wool as such is manufactured. Only one plant in this country is reported to use natural rock as the primary raw material. A combination of slag and rock typically constitutes the charge to the furnace. Approximately 70 percent of the mineral wool sold in the United States is manufactured from blast furnace slag.[25] Most of the remainder is produced using copper, lead, or phosphate slag.

In a typical mineral wool manufacturing plant, the raw material (slag and rock) is loaded into a cupola in alternating layers with coke. As the coke is ignited and burned, the mineral charge is heated to the molten state at a temperature of 2400 to 3000°F. Combustion air is supplied through tuyeres located near the bottom of the furnace. This air is enriched with oxygen in some processes. Auxillary burners fired with natural gas may also be used to reduce the consumption of coke.

The molten mineral charge exits the bottom of the cupola in a water-cooled trough and falls onto a fiberization device. Most of the mineral wool produced in the United States is made by variations of two fiberization methods. The Powell process, as shown in Figure 4-2, uses groups of rotors revolving at a high rate of speed to form the fibers. Molten material is distributed in a thin film on the surfaces of the rotors and then is thrown off by centrifugal force. Small globules develop that trail long, fibrous tails as they travel horizontally. Air or steam may be blown around the rotors to assist in fiberizing the

material. A second fiberization method, the Downey process (shown in Figure 4-3), uses a spinning concave rotor with air or steam attenuation. Molten material is distributed over the surface of the rotor where it flows up and over the edge to be caught up in a high velocity stream of air or steam. The configuration of the rotor varies from process to process and may spin either in a vertical or horizontal plane. The point at which the molten stream contacts the rotor can also vary.

During the spinning process, not all the globules that develop are converted into fiber. The non-fiberized globules that remain are referred to as "shot." In raw mineral wool, as much as half of the mass of the product may consist of shot.[25] Shot is usually separated from the wool by gravity immediately following fiberization. Some of this waste has reportedly been used in sandblasting but, in general, it represents a disposal problem for mineral wool producers.[26] Commercial standards for mineral wool insulation generally limit the maximum shot content of the material since shot is a poor insulator which takes up space that could be better utilized if occupied by air.

Various chemical agents may be applied to the newly-formed fiber immediately following the rotor. In almost all cases, an oil is applied to suppress dust and, to some degree, anneal the fiber. This oil can either be a proprietary product developed for this use or a medium weight fuel or lubricating oil. If the fiber is intended for use as loose wool or bulk products, no further chemical treatment is necessary. Where the mineral wool product is required to have structural rigidity, as in batts and industrial felt, a binding agent is applied with or in place of the oil treatment. This binder is typically a phenol- formaldehyde resin

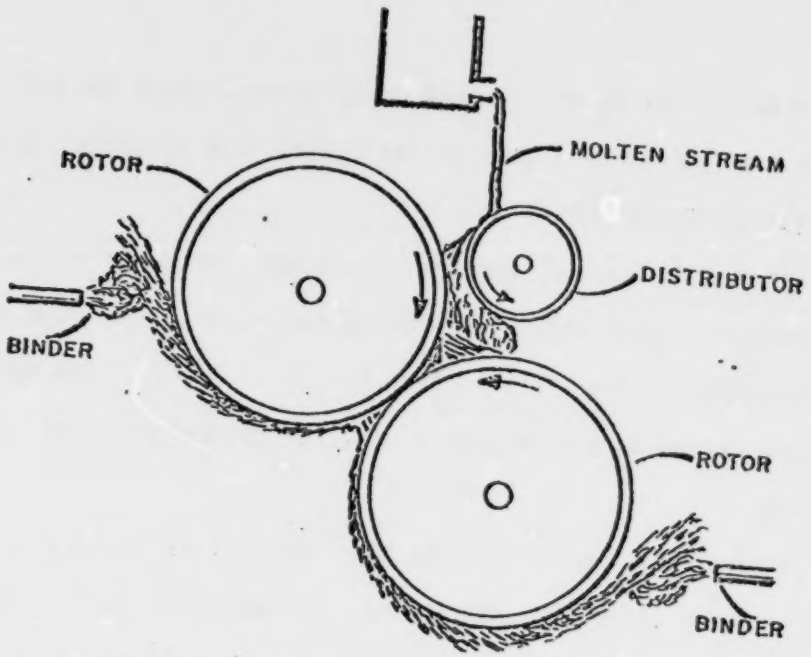


FIGURE 4-2. POWELL PROCESS

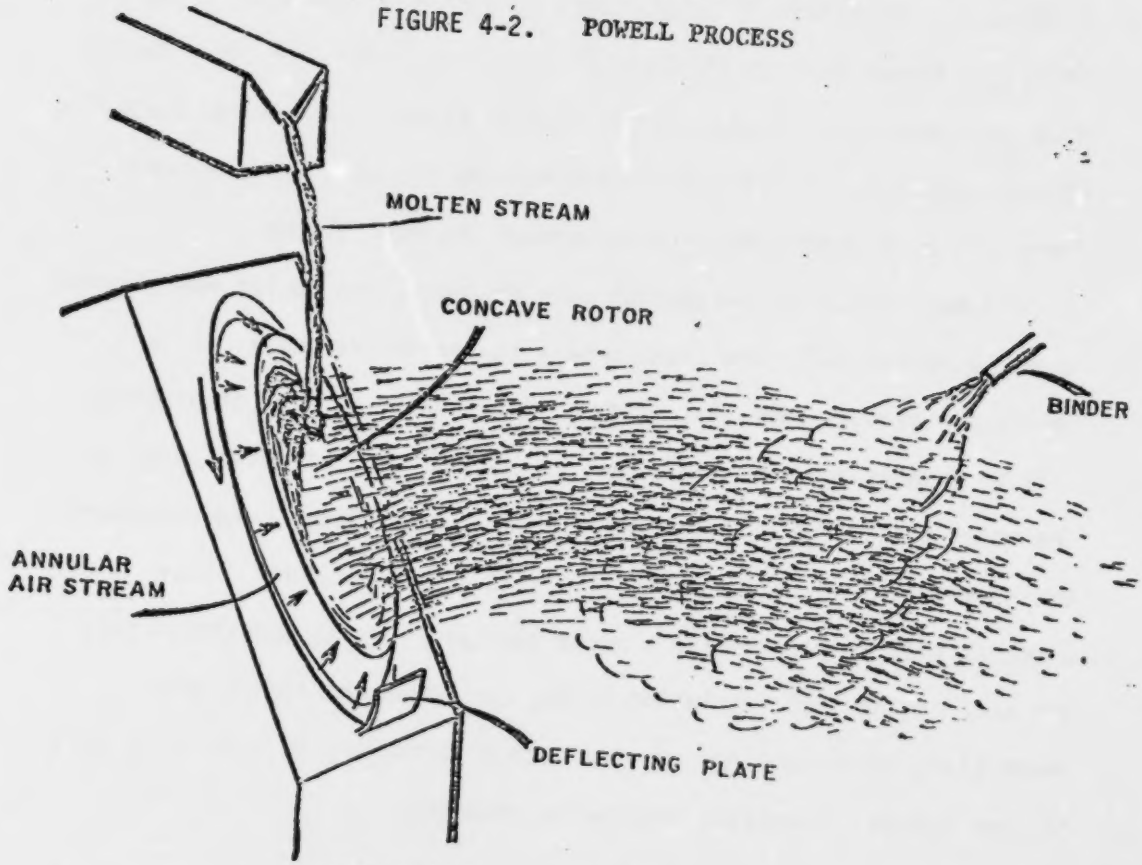


FIGURE 4-3. DOWNEY PROCESS

SOURCE: Reference 27

that requires curing at elevated temperatures. Both the oil and the binder are applied by atomizing the liquids and spraying the agents to coat the air-borne fiber.

After formation and chemical treatment, the fiber is collected in a blowchamber. Resin and/or oil-coated fibers are drawn down on a wire mesh conveyor by fans located beneath the collector. The speed of the conveyor is set so that a wool blanket of desired thickness can be obtained.

Mineral wool containing the binding agent is carried by conveyor to a curing oven where the wool blanket is compressed to the appropriate density and the binder is baked. Hot air, at a temperature of 300 to 600°F, is forced through the blanket until the binder has set. Curing time and temperature depend on the type of binder used and the mass rate through the oven. A cooling section follows the oven where blowers force air at ambient temperatures through the wool blanket.

To make batts and industrial felt products, the cooled wool blanket is cut longitudinally and transversely to the desired size. Some insulation products are then covered with a vapor barrier of aluminum foil or asphalt-coated kraft paper on one side and untreated paper on the other side. The cutters, vapor barrier applicators, and conveyors are sometimes referred to collectively as a batt machine. Those products that do not require a vapor barrier, such as industrial felt and some residential insulation batts, can be packed for shipment immediately after cutting. A wire mesh covering may be applied by hand to some special industrial insulation products.

Loose wool products consist primarily of blowing wool and bulk fiber. For these products, no binding agent is applied, and the curing oven is eliminated. For granulated wool products, the fiber blanket leaving the blowchamber is fed to a shredder and pelletizer. The pelletizer forms small, 1-inch diameter pellets and separates shot from the wool. A bagging operation completes the processes. For other loose wool products, fiber can be transported directly from the blowchamber to a baler or bagger for packaging. Figure 4-4 shows the typical mineral wool process flow diagram.

Adoption of new technical innovations in the mineral wool industry has been slow. One plant currently in operation uses a reverberatory furnace instead of a cupola for the melting of slag and rock. Electric furnaces have received considerable attention as possible substitutes for cupolas, but none are currently in operation in the United States. However, a single line mineral wool plant currently under construction in Woodbridge, Virginia, is reportedly installing an electric furnace.[28] Although the use of electric furnaces would reduce the air pollution problems associated with cupolas, there has been difficulty in developing a commercially viable refractory lining that can resist the corrosive and erosive effects of slag in continuous melting operations.[29]

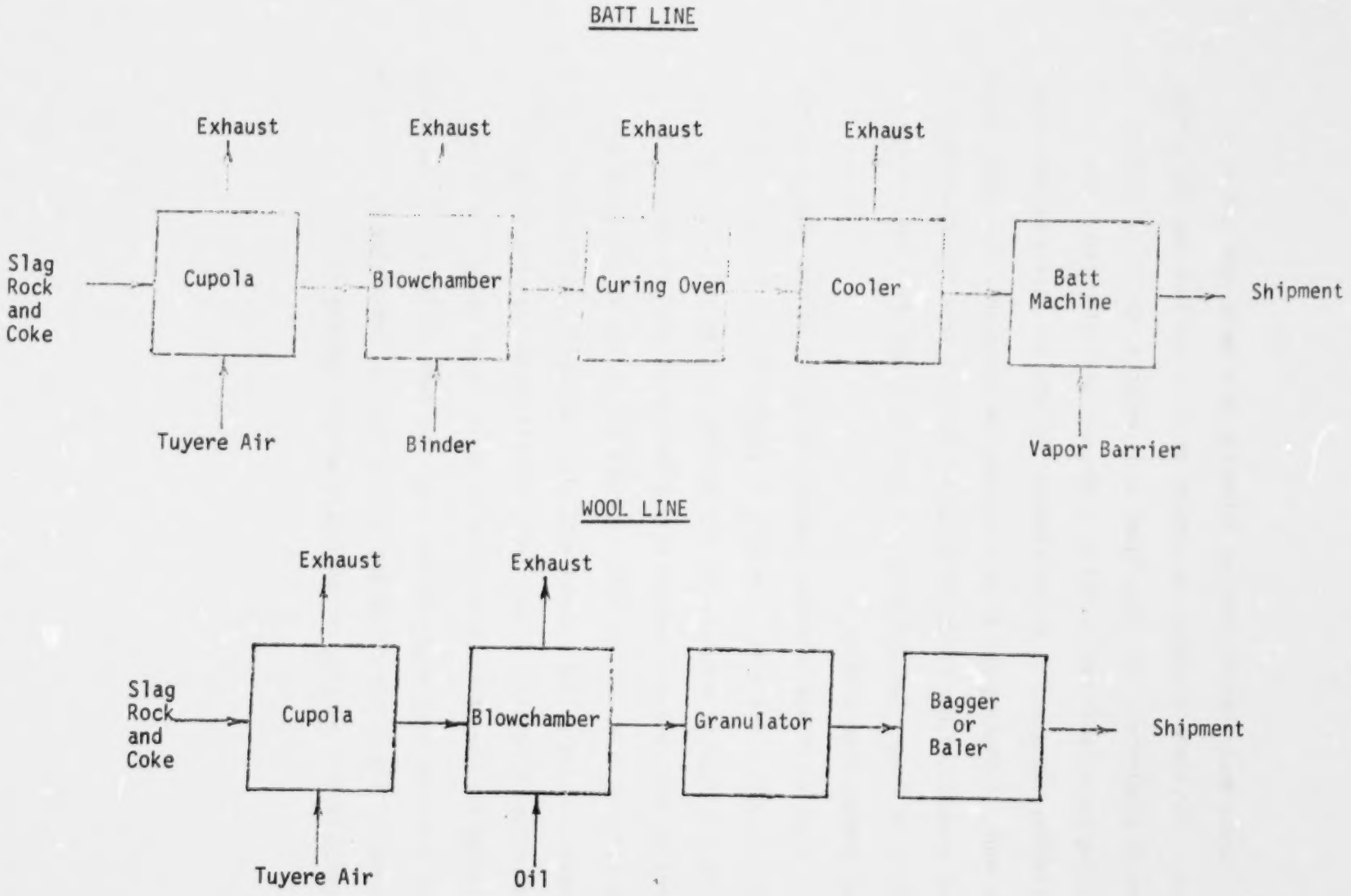


FIGURE 4-4. TYPICAL MINERAL WOOL PROCESS FLOW DIAGRAM

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5. AIR EMISSIONS DEVELOPED IN THE SOURCE CATEGORY

5.1 PLANT AND PROCESS EMISSIONS

This chapter identifies the types and quantities of emissions from several potential emission points within a typical mineral wool manufacturing plant. Cupola and blowchamber emissions are common to essentially all mineral wool plants. Emissions from other process points such as curing ovens and coolers occur when this equipment exists in the plant configuration and is being used to manufacture products requiring their operation. In the discussion which follows, emission data and emission factors from traditional sources have been compiled.[1,2] References 1 and 2 will be referred to as AP-40 and AP-42, respectively, throughout the remainder of Chapters 5 and 6. In addition, emission test data were requested from the majority of local and State control agencies having jurisdiction over existing mineral wool plants. The agencies for the States of Indiana, Missouri, and Alabama and the South Coast Air Quality Management District of California furnished data for this study. Emission data from the open literature and test data from control agencies were compiled and then calculations were performed as necessary to reduce the data to pollutant concentrations and emission factor format. In the discussion that follows, a test point usually is an average of three tests for the emission source. Generally, emission factors were estimated by using previously reported data; e.g., from

AP-40, plus the data obtained during this study to calculate average emission factors based on all available data. Exceptions to this general procedure will be noted in the test.

5.1.1 Furnace Emissions

Mineral wool is manufactured using cupolas as the melting furnace at most plants in this country. One plant has a reverberatory furnace supplying mineral wool fiber to several parallel processing lines. A plant using an electric melting furnace is expected to be in operation in 1980. Since cupolas are by far the most common furnace in the industry, as would be expected, the majority of furnace test data describes cupola emissions.

5.1.1.1 Particulate Emissions - Table 5-1 contains a summary of uncontrolled particulate emission data that is reported in AP-40 as well as data that were assembled during this source category survey. The uncontrolled emission factor reported in AP-42 is 11 kg/Mg (22 lbs/ton) which is apparently based upon the 3 cupola emission tests reported in AP-40 which are summarized on the first line in Table 5-1.

The uncontrolled emission factor for cupola particulate emissions used in this study to estimate typical plant emissions as well as total national emissions for the industry is an average of the AP-40 data plus the three additional tests obtained during this source category survey. The resulting uncontrolled emission factor is 8 kg/Mg (16 lbs/ton).

The results from only one particle size analysis were available from the agency data. The test data from an Andersen sampler analysis of uncontrolled particulate from a cupola were:[3]

Table 5-1. Uncontrolled Particulate Emissions from Mineral Wool Cupolas

Number of Tests	Dust Concentration mg/scm (gr/scf) Range	Dust Concentration mg/scm (gr/scf) Average	Emission Factor kg/Mg (lbs/ton) Range	Emission Factor kg/Mg (lbs/ton) Average	Reference
3	1630.0 to 2930.0 (0.71 to 1.28)	2410.0 (1.05)	8.0 to 14.1 (16.0 to 28.2)	10.8 (21.6)	AP-40
3	1350.0 to 5250.0 (0.59 to 2.29)	3140.0 (1.37)	2.3 to 6.8 (4.6 to 13.7)	5.3 (10.6)	Present study
	--	--	--	11 (22)	AP-42

Particle size range, μm	Percent by weight
+ 30	5.6
9.2 to 30	0.1
5.5 to 9.2	0.5
3.3 to 5.5	1.0
2.0 to 3.3	5.0
1.0 to 2.0	67.8
0.2 to 1.0	20.0

There is one emission test reported in AP-40 for particulate emissions from a reverberatory melting furnace of approximately 2.5 kg/Mg (5 lbs/ton) which is also the emission factor reported in AP-42. No further test data for reverberatory furnaces were obtained during this source category survey.

5.1.1.2 Sulfur Compound Emissions - The only other emission factor contained in AP-42 for cupola emissions is that reported for sulfur oxides. Table 5-2 contains a summary of test data from AP-40 and data obtained during this source category survey.

The emission factor for sulfur oxides in AP-42 significantly underestimates the emissions of sulfur oxides from mineral wool cupolas. The 0.01 kg/Mg (0.02 lbs/ton) emission factor seems to be in error since AP-40 is used as a reference but, as shown in Table 5-2, the one sulfur oxide data point from AP-40 was reduced to an emission factor and was found to be much larger than the reported value in AP-42. An emission factor of 5.5 kg/Mg (11 lbs/ton) based on the data collected in this source category survey and the one test result reported in AP-40 was used to estimate uncontrolled sulfur oxides emissions from mineral wool cupolas.

The one test from AP-40 where the concentration of sulfur trioxide was identified is worth noting since about 36 percent by weight of the sulfur oxides were reported to be emitted as sulfur trioxide in this test. This result is of interest since, as will be discussed later, severe corrosion

Table 5-2. Average Uncontrolled Sulfur Oxides and Hydrogen Sulfide Emission Concentrations and Factors for Mineral Wool Cupolas

Sulfur Dioxide		Sulfur Trioxide		Total Sulfur Oxides		Hydrogen Sulfide		
Flue Gas Concentration (ppm)	Emission Factor kg/Mg (lbs/ton)	Flue Gas Concentration (ppm)	Emission Factor kg/Mg (lbs/ton)	Emission Factor kg/Mg (lbs/ton)		Flue Gas Concentration (ppm)	Emission Factor kg/Mg (lbs/ton)	Reference
--	--	--	--	0.01	(0.02)	--	--	AP-42*
430	5.5 (11.1)	200	3.2 (6.3)	8.7	(17.4)	--	--	AP-40**
86 to 1120	5.3 (10.6)	--	--	5.3	(10.6)	150 to 500	1.5 (3.0)	Present study**
500	--	--	--	--		--	--	SIP****

* Test results upon which emission factor is based could not be identified.
** One test value for SO_2 and SO_3 available from this source.
*** Ten test results for sulfur dioxide and three tests for H_2S were obtained during this study.
**** One agency having jurisdiction over a mineral wool plant has an emission standard for SO_2, a maximum concentration of 500 ppm.

problems in the baghouse structures were observed at several of the plants visited during the study.

There were three tests in which hydrogen sulfide emissions from mineral wool cupolas were reported. Two tests from a Canadian study showed concentrations of about 150 and 190 ppm hydrogen sulfide with emission factors of 0.4 (0.8) and 0.5 kg/Mg (1.0 lbs/ton), respectively, for two tests.[4] Additionally, one test for a United States plant was reported where the flue gas concentration was 500 ppm with a 3.6 kg/Mg (7.14 lbs/ton) hydrogen sulfide emission factor.[5] An average of these three tests was used to estimate emissions from both a typical mineral wool plant as well as to estimate national emissions, the resulting emission factor being equal to 1.5 kg/Mg (3.0 lbs/ton).

5.1.1.3 Carbon Monoxide Emissions - There are significant amounts of carbon monoxide produced by mineral wool cupolas although neither AP-40 nor AP-42 report test data or an emission factor for this pollutant. There were a total of nine tests that were obtained for uncontrolled carbon monoxide emissions from mineral wool cupolas during this study. As can be seen in Table 5-3, there is a wide range of both carbon monoxide concentration in the flue gas and emission factor values. This wide range may be explained in part by various amounts of dilution air entering the cupola exhaust systems from plant to plant and possibly by the various analytical methods used to test for carbon monoxide. Some of the values were developed by Orsat analysis while other results were based on highly sophisticated gas chromatographic analytical techniques.

Table 5-3. Uncontrolled Carbon Monoxide Emissions from Mineral Wool Cupolas

Number of Tests	Flue Gas Concentration (ppm) Range	Average	Emission Factor kg/Mg (lbs/ton) Range	Average	Reference
9	1,000 - 83,000	23,400	3 - 156 (6 - 312)	78 (156)	Present study

Table 5-4. Uncontrolled Nitrogen Oxides Emissions from Mineral Wool Cupolas

Number of Tests	Flue Gas Concentration (ppm) Range	Average	Emission Factor kg/Mg (lbs/ton) Range	Average	Reference
6	13 - 125	39	0.1 - 1.9 (0.2 - 3.7)	0.8 (1.6)	Present study

For the estimate of typical plant and national emissions of carbon monoxide, an emission factor of 78 kg/Mg (156 lbs/ton) was used. This factor is an average of nine test results collected during this source category survey.

5.1.1.4 Nitrogen Oxides Emissions - For six emission tests obtained from the control agencies, nitrogen oxides were analyzed and reported for cupola exhaust gases. This data is summarized in Table 5-4. The average of these tests, an emission factor of 0.8 kg/Mg (1.6 lbs/ton), was used to estimate typical plant and national emissions for mineral wool manufacturing.

5.1.2 Blowchamber Emissions

Most mineral wool plants have a blowchamber immediately following the fiberizing step in the process. The exhaust gas from the blowchamber fans is usually treated by a control device to remove entrained flywool or lint before it is exhausted to the atmosphere.

5.2.1.2 Blowchamber Particulate Emissions - Table 5-5 contains uncontrolled dust concentration and emission factor data for mineral wool blowchamber exhausts. The AP-42 uncontrolled emission factor of 17 lbs/ton could also be related to the AP-40 data just as it could for the cupola emission factor. The emission factor used for blowchamber emission estimates in this study is a value of 6 kg/Mg (12 lbs/ton). This factor is based upon the overall average of the four tests from AP-40 and the two test results obtained from control agencies during this study.

5.1.2.2 Blowchamber Volatile Organic Compound Emissions - The only pollutants other than particulate that were identified as being emitted from mineral wool blowchambers from the literature and this source

Table 5-5. Uncontrolled Particulate Emissions from Mineral Wool Blowchambers

Number of Tests	Dust Concentration mg/scm (gr/scf) Range	Dust Concentration mg/scm (gr/scf) Average	Emission Factors kg/Mg (lbs/ton) Range	Emission Factors kg/Mg (lbs/ton) Average	Reference
4	121 - 914 (0.053 - 0.399)	298 (0.13)	1.3 - 27.8 (2.6 - 55.6)	8.6 (17.2)	AP-40
2	22.2 - 24.0 (0.0097 - 0.0105)	23.1 (0.0101)	0.7 - 0.9 (1.4 - 1.8)	0.8 (1.6)	Present study
--	--	--	--	17	AP-42

category survey are volatile organic compounds (VOC). An annealing oil is applied to mineral wool at the point where fibers are formed to control flywool generation. When batts are manufactured, a resin is applied in place of, or in addition to, the oil. This resin may contribute to VOC emissions. The relatively low temperatures in blowchamber exhaust streams of about 180°F might result in condensation of the oils and binders and thereby emission to the atmosphere as particulate matter. Two test results, both from the same plant, were obtained during this study; the result of these two tests is an average of 0.2 kg/Mg (0.4 lbs/ton) of total VOC, reported as methane. One result is reported in AP-40 for a test of aldehydes in the exhaust from a mineral wool blowchamber; this result is an emission factor of 0.86 lbs/ton as total aldehydes.

Since data was reported using different bases, the higher test result or an emission factor value of 0.45 kg/Mg (0.9 lbs/ton) of VOC as aldehydes from the blowchamber was used in this study to make typical plant and national VOC emission estimates for mineral wool manufacturing.

5.1.3 Curing Oven Emissions

The available test results for uncontrolled particulate emissions from mineral wool curing ovens are reported in Table 5-6. The average emission factor estimate using the AP-40 values is 2 kg/Mg (4 lbs/ton) which was used to make typical plant and national emissions estimates for particulate matter from mineral wool manufacturing. This is the same emission factor reported in AP-42 for this source.

Total VOC results were not reported in the data reviewed, but tests for aldehydes were reported in AP-40 for the inlet and outlet in two afterburner tests. The two reported inlet values were used to calculate an average emission factor of 0.5 kg/Mg (1 lbs/ton) for uncontrolled

Table 5-6. Uncontrolled Particulate Emissions from Mineral Wool Curing Ovens

Number of Tests	Dust Concentration mg/scm (gr/scf) Range	Dust Concentration mg/scm (gr/scf) Average	Emission Factor kg/Mg (lbs/ton) Range	Emission Factor kg/Mg (lbs/ton) Average	Reference
6	275 - 961 (0.12 - 0.42)	484 (0.21)	0.75 - 2.95 (1.50 - 5.9)	1.82 (3.63)	AP-40
--	--	--	--	2 (4)	AP-42

aldehydes from a mineral wool curing oven. This emission factor was used to make VOC emission estimates for a typical plant as well as nationwide emissions.

Two test results for nitrogen dioxide emissions from curing ovens are reported in AP-40 at the inlet to afterburners used for control of VOC emissions. The average of these two tests is a 0.08 kg/Mq (0.16 lbs/ton) emission factor; this factor was used to estimate oxides of nitrogen emissions from an uncontrolled curing oven.

5.1.4 Mineral Wool Cooler Emissions

There were no data obtained for emissions from mineral wool coolers during the source category survey other than four tests for particulates contained in AP-40. These test result in an average emission factor of about 1 kg/Mg (2 lbs/ton) which is also the emission factor reported in AP-42. The 1 kg/Mg emission factor was used to make subsequent emission estimates of particulate matter for a typical plant and nationwide emissions.

For one of the four emission tests noted above, a test for total aldehydes was conducted. The result of this test is an emission factor estimate of 0.02 kg/Mg (0.04 lbs/ton) of total aldehydes which was used to make typical plant and nationwide VOC emission estimates.

5.1.5 Asphalt Application

Asphalt vapors can be emitted during application of the asphalt film to the paper backing used when manufacturing insulation batts. These emissions reportedly can be reduced by proper temperature control of the application process.[6] An asphalt applicator was operating at only one plant visited during this source category survey; no visible emissions

were apparent while observing this operation. No emission test data for this operation were obtained from either the literature or the agencies contacted during this study. For these reasons, this emission source was not further considered during the study.

5.2 UNCONTROLLED ANNUAL EMISSIONS FOR A TYPICAL MINERAL WOOL PLANT

A typical mineral wool manufacturing plant was assumed to consist of two cupola lines with each line having the following production rates:

Cupola charging rate - 2.73 Mg/hour (3 tons/hour) with 8400 operating hours/year

Blowchamber - 1.64 Mg/hour (1.8 tons/hour) with 8400 operating hours/year.

The cupola production rate is approximately the average and median rate for the mineral wool industry in late summer of 1979. The blowchamber operating rate assumes a 60 percent conversion of cupola charge to usable fiber. One of the lines is also assumed to have a curing oven and cooler with a production rate of 1.64 Mg/hour (1.8 tons/hour) which operates for 4200 hours/year. It is assumed that this line manufactures blowing wool when batts are not being manufactured.

Table 5-7 contains a compilation of all of the emission factors used to make the emissions estimate for a typical plant and for the industry. Table 5-8 contains the annual uncontrolled emissions from a typical mineral wool plant operating at the specified conditions.

The emissions from a typical mineral wool plant controlled to meet the requirements of a typical SIP are contained in Table 5-9. The only standard from a SIP that can be considered to apply to mineral wool plants is the process weight regulation for particulates where

Table 5-7. Uncontrolled Emission Factors for Mineral Wool Manufacturing - kg/Mg (lbs/ton)

Process Source	Particulates	Sulfur Oxides	Hydrogen Sulfide	Carbon Monoxide	VOC	Nitrogen Oxides
Cupola	8 (16)	5.5 (11)	1.5 (3.0)	78 (156)	--	0.8 (1.6)
Blowchamber	6 (12)	--	--	--	0.45 (0.9)	--
Curing Oven	2 (4)	--	--	--	0.5 (1.0)	0.08 (0.16)
Cooler	1 (2)	--	--	--	0.02 (0.04)	--

Table 5-8. Uncontrolled Potential Emissions from a Typical Mineral Wool Manufacturing Plant - Mg/yr (tons/yr)

Process Source	Particulates	Sulfur Oxides	Hydrogen Sulfide	Carbon Monoxide	VOC	Oxides of Nitrogen
Cupola	366 (403)	252 (277)	69 (76)	3,570 (3,930)	--	37 (40)
Blowchamber	165 (181)	--	--	--	12 (14)	--
Curing Oven	14 (15)	--	--	--	3 (4)	1 (1)
Cooler	7 (8)	--	--	--	< 1 (<1)	--
TOTALS	552 (607)	252 (277)	69 (76)	3,570 (3,930)	15 (18)	38 (41)

$E = 3.59\ p^{0.62}$ has been found to be typical in this study. Using this regulation, the controlled emission factors were found to be 1.18 kg/Mg (2.36 lbs/ton) for mineral wool cupolas and 1.43 kg/Mg (2.87 lbs/ton) for mineral wool blowchambers and curing ovens. Although some States regulate sulfur dioxide emissions with regulations in the range of 500 to 2000 ppm, these concentrations are in excess of most cupola flue gas concentrations of sulfur dioxide reviewed in this study. Therefore, the SIP's were not considered to result in reduction of mineral wool sulfur oxides emissions.

5.3 TOTAL NATIONWIDE EMISSIONS FROM MINERAL WOOL MANUFACTURING

Total potential nationwide emissions for the mineral wool manufacturing industry are contained in Table 5-10. The assumptions upon which this estimate is based include:

- Cupola charge capacity for the mineral wool industry is estimated to be 1.23×10^6 Mg/year (1.35×10^6 tons/year). This estimate is based upon individual plant data obtained from NEDS and from the source category plant visits. Where the cupola charge rate was not provided or considered confidential, an average plant capacity was substituted for the unknown value.

- The conversion rate from total cupola charge to actual mineral fiber produced for further processing through the blowchamber was assumed to be 60 percent. This factor makes allowance for the coke in the cupola charge and for the "shot" produced from the cupola which cannot be further processed.

Table 5-9. Potential Emissions from a Typical Mineral Wool Manufacturing Plant Controlled to Meet a Typical SIP - Mg/year (tons/year)

Process Source	Particulates	Sulfur Oxides	Hydrogen Sulfide	Carbon Monoxide	VOC	Nitrogen Oxides
Cupola	54 (60)	252 (277)	69 (76)	3,570 (3,930)	--	37 (40)
Blowchamber	39 (43)	--	--	--	12 (14)	--
Curing Oven	10 (11)	--	--	--	3 (4)	1 (1)
Cooler	7 (8)	--	--	--	< 1 (<1)	--
TOTALS:	110 (122)	252 (277)	69 (76)	3,570 (3,930)	15 (18)	38 (41)

Table 5-10. Nationwide Potential Emissions from the Mineral Wool Manufacturing Industry for 1979 Assuming Compliance with SIP's - Mg/year (tons/year)

Process Source	Particulates	Sulfur Oxides	Hydrogen Sulfide	Carbon Monoxide	VOC	Oxides of Nitrogen
Cupolas	1,450 (1,600)	6,750 (7,420)	1,850 (2,040)	95,600 (105,300)	--	980 (1,080)
Blowchamber	1,040 (1,150)	--	--	--	330 (360)	--
Curing Oven	270 (290)	--	--	--	150 (170)	25 (27)
Cooler	190 (210)	--	--	--	15 (17)	--
TOTALS:	2,950 (3,250)	6,750 (7,420)	1,850 (2,040)	95,600 (105,300)	495 (547)	1,005 (1,107)

- It was estimated that one-fourth of the plant production for the industry is processed through a curing oven and cooler. Information obtained during the source category survey indicated that typically one production line had a curing oven and cooler that were used about half of the production schedule on that line.

- Baseline control was assumed to apply only to particulate emissions from cupolas, blowchambers, and curing ovens of a mineral wool plant.

- Baseline control was considered to be emissions in lbs/hour determined from $E = 3.59\ p^{0.62}$, where p is the process weight rate in tons/hour.

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6. EMISSION CONTROL SYSTEMS AND ENVIRONMENTAL IMPACT

6.1 CURRENT CONTROL TECHNOLOGY PRACTICES

Several sources of information were utilized to obtain data describing the application of control technologies to emission points in the mineral wool process. The data were obtained from discussions with plant personnel during industry visits, contacts with State and local control agencies, and summaries from the National Emission Data System (NEDS). Only the common process emission points - cupolas, blowchambers, curing ovens, and coolers - were considered in developing this summary of control technology practices in the industry. Some miscellaneous sources; e.g., sawing of ceiling tile, mixing of industrial cement, etc., were identified in data from the States or NEDS but were usually found in only one or two plants in the industry.

A summary of the control technologies reported in use for the mineral wool industry is contained in Table 6-1. The fact that there is not a one-to-one relationship in Table 6-1 of cupolas to blowchambers is apparently due to combining cupola product streams at some plants prior to entry into the blowchamber. As has been stated earlier, there is usually no more than one curing oven in a mineral wool plant which accounts for the considerably fewer number of them compared to cupolas. Presumably, coolers are not considered significant enough of a source to warrant reporting in most cases.

Table 6-1. Summary of Air Pollution Controls Operating in the United States Mineral Wool Industry

Process Source	Total	Number of Process Sources Controlled by Indicated Devices							
		Fabric Filters	ESP	Wet Scrubbers	Cyclones	Afterburners	Lint Cages	Other	None
Cupolas[a]	53	35	2	3	20	2	0	2[b]	3
Blowchambers[c]	46	2	0	21	3	2	9	0	12
Curing Ovens	15	1	0	0	0	6	0	0	8
Coolers	6	0	0	0	0	1	0	0	5

[a] Two cupolas are controlled with fabric filters followed by direct-flame afterburners; two cupolas are controlled by wet scrubbers followed by ESP; seven cupolas are controlled by cyclones followed by baghouses; and one cupola is controlled by a cyclone followed by a wet scrubber.
[b] Carbon monoxide control system is operating on two cupolas with a baghouse in one plant.
[c] Three blowchambers use two control devices in series; two plants use afterburners plus wet scrubbers and one plant has cyclones plus a baghouse.

6.1.1 Cupola Emission Control Systems

6.1.1.1 Control of Particulate Emissions - Control of particulate emissions from cupolas has received more emphasis than control of any other air pollutant from the industry. Table 6-1 shows fabric filtration as the most commonly applied control technology for mineral wool cupola particulate emissions. The next most commonly applied control technique is dry centrifugal collection of particulates emitted from cupolas.

In Table 6-2, emission data have been summarized to illustrate the effectiveness of the various particulate collectors for control of cupola emissions. The last line in the table shows the dust concentration and emission factor that would meet compliance with a typical State Implementation Plan (SIP) particulate regulation. There are several plants in the industry which use only cyclones for cupola particulate emission control. These devices have the capability on occasion to meet the typical SIP process weight regulation, but compliance is the exception rather than the rule. There is only one test for a wet scrubber, but this one result would not comply with the typical SIP. All of the fabric filtration results demonstrated capability of meeting the SIP regulation; in fact, the highest test result reported is lower than the SIP regulation by more than a factor of four.

Corrosion of the baghouse structure or auxilliary equipment was observed or reported at two plants which were visited during the study. The corrosion problem experienced at one plant was severe enough to justify enclosing the baghouse and making provision to heat the area. When climatic conditions were severe enough, the moisture condensed from the flue gas was reported to not only "blind" the bags but may literally freeze solid in the bags,

Table 6-2. Controlled Particulate Emissions from Mineral Wool Cupolas

Number of Tests	Control Equipment	Concentration mg /scm (gr/scf) Range	Concentration mg /scm (gr/scf) Average	Emission Factor kg/Mg (lbs/ton) Range	Emission Factor kg/Mg (lbs/ton) Average	Reference
6	Fabric filter	8.48 to 96.1 (0.0037 to 0.042)	46.7 (0.0204)	0.0022 to 0.35 (0.0044 to 0.70)	0.21 (0.42)	Present study
1	Wet Scrubber	--	451 (0.197)	--	1.1 (2.2)	Present study
7*	Cyclones	192 to 641 (0.084 to 0.28)	330 (0.144)	0.85 to 1.5 (1.7 to 3.0)	1.15 (2.3)	Present study
	To comply with regulation	--	286 (0.125)	--	1.18 (2.36)	Typical SIP

* Dust concentration was reported for seven tests, but sufficient data to calculate emission factors were available for only five of the tests.

according to the plant operator, necessitating replacement of the bags. At a second plant, there was visible deterioration of exposed metal surfaces of ducts and baghouse structure after approximately 18 months of operation. At a third plant, the baghouse was located inside the plant, but the plant manager reported there had been condensation inside the baghouse but no resultant corrosion

For the three plants visited but not experiencing serious corrosion problems, one controlled cupola emissons with cyclones, another did not have controls operating, and the third was equipped with a baghouse but reported insignificant corrosion problems, presumably due to the relatively mild winter climate.

6.1.1.2 Control of Carbon Monoxide Emissions - One plant in the United States has an operating system for control of cupola carbon monoxide emissions. This plant was visited as part of the source category survey and the following discussion is based upon that visit.[1] The system was tested in June 1979, and the carbon monoxide concentration based on an average of two tests was 1,000 ppm. Simultaneous inlet concentrations were not measured during the 1979 test, but the average inlet concentration was 70,000 ppm for a July 1977 test. Using these two different tests, an estimate of the control efficiency for carbon monoxide would be in excess of 98 percent.

Natural gas and air are injected into some cupolas to supplement the coke fuel in the charge to the cupola. Control agency personnel monitored a test about 3 hours in duration to determine if CO emissions were affected by altering the natural gas and air mixture to a cupola. The cupola was normally run with natural gas and air flows on. This

normal condition was followed by a run with the gas flow off and the air flow on. Then the air, which usually is injected with the gas, was also turned off. The author concluded that there was no effect upon CO emissions under these various conditions.[2]

6.1.1.3 Control of Sulfur Compound Emissions - There has been a system reported in operation at a Canadian mineral wool plant for the control of cupola hydrogen sulfide emissions.[3] The control system consists of a baghouse and hydrogen sulfide removal reactor in series. The hydrogen sulfide reactor consists of two beds of hematite iron ore pellets supported by perforated plates; the flue gas can be diverted to either bed so that an inactive bed can be removed for catalyst regeneration. Sulfur and dust are recovered from the ore pellets by screening and are either discarded or recovered for sale. Two tests of the system have demonstrated hydrogen sulfide removal efficiencies of 85 and 90 percent, respectively. This system also results in reduction of sulfur dioxide emissions by 42 to 75 percent.[4]

A test for evaluation of a pilot baghouse for cupola particulate control has also shown reduction of sulfur dioxide emissions. Inlet and outlet SO_2 tests of the baghouse demonstrated a 68 percent reduction in SO_2 emissions.[5] The apparent explanation for this partial sulfur dioxide control was the charging of limestone with the normal coke and slag charge to the cupola.

6.1.2 Blowchamber Emission Control Systems

6.1.2.1 Control of Particulate Emissions - The particulate emissions from the blowchambers of mineral wool plants are usually controlled. This fact seems to be due to the nature of these emissions,

primarily "fly wool;" i.e., fibrous particles that are relatively large, are readily visible, and can create a nuisance when they accumulate in the area of the plant. There is also some smoke or haze generated from the vaporization or decomposition of the annealing oil applied to the fiber as it is being formed at the spinner. When batts are being manufactured, there may also be some of the resin emitted as either a particulate or gaseous decomposition product.

Table 6-1 shows that the most commonly used control devices for blowchambers are wet scrubbers. The devices that were observed during this study were low energy scrubbers, generally baffled spray chambers. When the large fly wool particles are collected in these devices, a residue builds up which must be automatically removed or cleaned out manually during process down time.

The next most commonly used device is a simple wire mesh filter called a screen house, bull cage, or lint cage. This device is simply a chamber covered with a fine mesh screen through which the blowchamber air is discharged. The mat of fly wool that builds up on the screen must be removed manually, usually on a daily basis, sometimes using a water hose to dislodge the fiber from the screen.

Test data for controlled emissions from blowchambers that have been reported in AP-40 and test data obtained during this study have been summarized in Table 6-3. There are relatively few test results available, but the AP-40 data indicate a scrubber/ESP system, a lint cage, and a wet scrubber are capable of meeting an SIP standard. The data obtained during the source category survey indicate that spray chambers and a wet scrubber could meet the SIP standard. However, a test result for a

Table 6-3. Controlled Particulate Emissions from Mineral Wool Blowchambers

Number of Tests	Control Equipment	Dust Concentration mg /scm (gr/scf) Range	Dust Concentration mg /scm (gr/scf) Average	Emission Factor kg/Mg (lbs/ton) Range	Emission Factor kg/Mg (lbs/ton) Average	Reference
2	Spray chamber	7.56 to 22.2 (0.0033 to 0.0097)	14.9 (0.0065)	0.39 to 0.65 (0.78 to 1.3)	0.52 (1.04)	Present study
1	Wet scrubber + ESP	--	25.2 (0.011)	--	0.42 (0.84)	AP-40
1	Wet scrubber	--	49.4 (0.0216)	--	0.75 (1.5)	Present study
1	Lint cage	--	27.5 (0.012)	--	0.55 (1.10)	AP-40
1	Wet scrubber	--	64.1 (0.028)	--	0.87 (1.74)	AP-40
1	Wet cyclone	--	117 (0.051)	--	4.4 (8.8)	Present study
--	To comply with regulation	--	69.1 (0.0302)	--	1.44 (2.87)	Typical SIP

device reported to be a wet cyclone exceeded the SIP on both a dust loading and emission factor basis.

Two blowchambers at one plant location are reported to use dry centrifugal collectors to control blowchamber emissions. These cyclones may be process equipment rather than control devices since cyclones are commonly used to remove mineral wool from air streams prior to further processing steps in mineral wool plants. There is a substantial proportion of blowchambers, 20 percent of the total in this survey, which are reported to be uncontrolled.

6.1.2.2 Control of Volatile Organic Compound (VOC) Emissions - The only pollutants in addition to particulates that were identified in Chapter 5 as an emission from blowchambers were VOC's. One plant is reported to use an afterburner for control of blowchamber emissions although no test data were obtained for this application. Some reduction of VOC vapor emissions would be expected if blowchamber gases are controlled with an afterburner; some reduction of combustible particulate might also be achieved.

6.1.3 Curing Oven Emission Control Systems

In Table 6-1, the only control devices presently reported as in use on curing oven emissions are direct flame afterburners and one fabric filter. Test results are available for evaluation of several other control devices used in the past for removal of particulates from curing oven exhausts; these results are contained in Table 6-4. Each of the systems would be able to comply with the typical SIP regulation for particulates. No reports of test results for fabric filtration of curing oven exhausts were obtained during this study. The resin binder in the

Table 6-4. Controlled Particulate Emissions from Mineral Wool Curing Ovens

Number of Tests	Control Equipment	Dust Concentration mg/scm (gr/scf) Range	Average	Emission Factor kg/Mg (lbs/ton) Range	Average	Reference
1	ESP	38.9	(0.017)	0.36	(0.72)	Present study
1	Direct-flame afterburner	73.3	(0.032)	0.71	(1.42)	AP-40
1	Wet scrubber + ESP	190	(0.083)	1.13	(2.26)	AP-40
1	Catalytic afterburner	163	(0.071)	0.95	(1.90)	AP-40
--	To comply with regulation	275	(0.12)	1.44	(2.87)	Typical SIP

emitted curing oven particulate might make fabric filters an impractical control device by plugging the pores of the bags.

In AP-40, there is one test result for a catalytic afterburner and one test result for a direct-flame afterburner for inlet and outlet emissions of aldehydes. The direct-flame afterburner removed 57 percent and the catalytic afterburner 53 percent of aldehydes from the curing oven exhaust.

6.1.4 Cooler Emission Control Systems

The cooler is a relatively minor source of pollutants compared to the other emission points in a mineral wool plant as indicated by the emissions inventory for a typical plant in Table 5-9. There is a direct-flame afterburner reported in use to control cooler emissions at one plant. However, the usual practice apparently is not to control emissions from the cooler. Since the cooler is a minor source, it is not identified in most cases when plants report emission sources to the States. No test data were obtained for the evaluation of any cooler emission control devices.

6.1.5 Processing Changes to Reduce Emissions

6.1.5.1 Raw Material Composition - Sulfur compound emissions are related to the sulfur content of the coke and slag charged to the cupolas. The typical sulfur limit for coke is a maximum of 0.6 percent based on discussion with personnel at several plants visited during the source category survey. Another potential source of sulfur is that contained in the slag charged to the cupola. At one plant visited, it was the judgment of an official from the State control agency that sulfur compound emissions were associated with sulfur content of the slag.[6] The

sulfur content of the slag was reported as 1.64 percent based on the supplier's analysis, and an EPA analysis of the same slag was reported to be higher. A consultant to the plant estimated that hydrogen sulfide concentrations in the cupola exhaust had been reduced from the 500 ppm level to the 200 ppm level by changing slag suppliers thereby effecting a reduction in the sulfur content of the slag. Sample results for sulfur content of the slag after the change of suppliers were not available to help confirm this association. This plant also had a problem with high fines content of the slag which reportedly caused increased particulate emissions.[7] Photographs of the slag were shown with golf balls placed on the slag pile for comparison purposes. The slag seemed to consist of a much greater proportion of particles considerably smaller than the golf balls that had been observed at other plants visited during the source category survey.

6.1.5.2 Replacement of Cupolas with Electric Furnaces - An electric furnace is reportedly in operation in Europe, and a Canadian plant is also reported to be manufacturing mineral wool using an electric furnace.[8] A United States company plans to start mineral wool production using an electric furnace in 1980.[9] In addition to significantly lower emissions from an electric furnace, there are potentials for fuel savings and decreased losses due to shot production. A drawback to the use of electric furnaces is the highly corrosive and erosive action of the slag on the refractory lining.[10] In addition to possible economic consideration, discussions with plant personnel during the survey indicated some reluctance on the part of companies to be the first in the United States industry to operate an electric furnace. This observation is supported by the fact that two plants started up in 1978, and both plants installed cupola melting furnaces.[11,12]

6.2 ALTERNATIVE CONTROL SYSTEMS

The process steps that could be considered for further NSPS investigation are the cupola, blowchamber, and curing oven emission points. The cooler was not considered further due to the relatively low emission levels and the general lack of control technology applications in the industry for control of this emission point.

The alternatives for control of mineral wool plant emissions are contained in Table 6-5. All three of the alternatives address particulate control of the cupolas, blowchambers, and curing ovens. Only the first alternative considers control of cupola carbon monoxide emissions and curing oven VOC emissions.

6.3 IMPACT OF MINERAL WOOL MANUFACTURING ON AMBIENT AIR QUALITY

The impact that emissions from mineral wool manufacturing have on the ambient environment was evaluated by estimating maximum ground level concentrations using two simplified Gaussian dispersion models, PTDIS and PTMAX. Particulate and carbon monoxide emissions from cupolas and particulate emissions from blowchambers were included in this modelling analysis. Two cupola configurations were considered for the particulate concentration estimates; the first assumed a single cupola with exhaust gases treated by a control device to comply with a typical SIP particulate emission standard while the second case was considered to be a plant utilizing a baghouse to control particulate emissions. When cupola particulate emissions are controlled by fabric filtration, the gases from two cupolas usually exhaust to the baghouse, typically composed of several modules. For evaluating the impact of mineral wool process carbon monoxide (CO) emissions on the ambient environment, the two cupola configurations described above were considered to have no control

Table 6-5

Alternative Control Systems

	Control Technology*		
Alternative	Cupola	Blowchamber	Curing Oven
Alternative I	FF + CO Control System	WS	AB
Alternative II	VS + ESP	WS	None
Alternative III	FF	FF	None

* FF - fabric filter; VS - high energy venturi scrubber; WS - low energy wet scrubber; AB - afterburner

of CO emissions and also with a CO control system. The blowchamber was assumed to be designed to accept the fiber output from one cupola with an exhaust stack for each blowchamber at the plant.

Particulate emission rates complying with a SIP for the single cupola case and the blowchamber are contained in Chapter 8 of this report. The assumed values for gas temperature and flow rate are also contained in Chapter 8. For cupola baghouse control, exhaust gas flow is double that for the single cupola case, and the emission rate was considered to be equal to the average of the tests for fabric filtration control of cupola particulate emissions contained in Table 6-2. The stack heights for cupola exhausts were assumed to be 15.24 meters (50 feet) for the single cupola and the baghouse. The stack diameter for a single cupola was considered to be 0.914 meter (3 feet) while a baghouse stack for controlling two cupolas was assumed to be 1.22 meters (4 feet). The controlled CO emission rate from a cupola equipped with a control system was assumed to be 5 percent of the uncontrolled emission rate (control system efficiency of 95 percent). The modelling inputs outlined above were selected as typical based upon information collected during plant visits or obtained from State agencies and NEDS.

The results from dispersion estimates for particulate and CO concentrations around typical mineral wool plants are contained in Table 6-6 and Table 6-7, respectively.[13]

For particulate emissions from a cupola or a blowchamber complying with the typical SIP, the maximum 24-hour average concentration would be less than 3 percent of the national primary ambient air quality standard in either case while the maximum annual average particulate concentration would be less than 2 percent of the national primary ambient air quality

Table 6-6. Maximum 24-Hour and Annual Ground Level Particulate Concentrations Around Typical Mineral Wool Plants

(micrograms/cubic meter)

Plant Emission Source	Distance from Plant (m)	24-Hour Average		Annual Average	
		SIP Control	Baghouse Control	SIP Control	Baghouse Control
Cupola[1]	600	6.7	--	1.3	--
Cupola[2]	750	--	0.6	--	0.1
Blowchamber	600	6.0	2.0	1.2	0.4

[1] Plant controlled to meet SIP was assumed to have separate stack for each cupola.

[2] Plant controlled with baghouse was assumed to combine exhaust gases from two cupolas.

Table 6-7. Maximum 1-Hour and 8-Hour Ground Level Carbon Monoxide Concentrations Around Typical Mineral Wool Plants

(micrograms/cubic meter)

Plant	Distance from Plant (m)	1-Hour Average		8-Hour Average	
		No Control	CO Control System	No Control	CO Control System
Cupola[1]	600	1,770	88	890	44
Cupola[2]	750	1,890	94	940	47

[1] Plant not controlled with baghouse assumed to have separate stack for each cupola.

[2] Plant controlled with baghouse assumed to combine exhaust gases from two cupolas.

standard for either emission point. Baghouse control of the cupolas or a blowchamber would result in estimated maximum particulate concentrations less than 1 percent of the 24-hour average and annual average national primary ambient air quality standards. Although control of blowchamber emissions with a baghouse was reported for one plant (see Table 6-1) and therefore included in the modeling analysis, the lower blowchamber exhaust gas temperature, as compared to the cupola exhaust gas temperature plus increased moisture content of the gas when steam is used for fiber attenuation, might make blowchamber baghouse control impractical as a result of condensation and possible attendant corrosion problems.

The maximum 1-hour average CO concentration estimates for a cupola with a separate exhaust stack and for cupolas controlled with a baghouse are both less than 5 percent of the national primary ambient air quality standard for CO, and when controlled with a CO control system, both are estimated to be reduced to less than 1 percent of the 1-hour average standard. For an 8-hour averaging time, a cupola with a separate exhaust stack and cupolas with baghouse particulate control are estimated to result in maximum ambient CO concentrations less than 10 percent of the national primary ambient air quality standard and the estimated concentrations are reduced to less than 1 percent of the national primary ambient air quality standard for cupolas with CO control systems.

REFERENCES

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7. Memorandum from L. Anderson, United States Environmental Protection Agency, to J.U. Crowder, United States Environmental Protection Agency. October 2, 1979. Visit to Spring Hope Rockwool, Incorporated, Spring Hope, North Carolina.

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11. Reference 7.

12. Telecon. L. Anderson, United States Environmental Protection Agency, with E. Fulton, Texas Air Control Board. April 17, 1979. Mineral wool plants operating in Texas.

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7. EMISSION DATA

7.1 AVAILABILITY OF DATA

The emission data obtained from State and local control agencies during the conduct of this study are identified in Table 7-1. In some cases, where only data summaries have been obtained, more detailed data might be available from the control agencies and/or companies.

7.2 SAMPLE COLLECTION AND ANALYSIS

Reference methods are defined in 40 CFR Part 60 Appendix A for sample collection and analysis of air pollutants; specific EPA reference methods that may be applied to the evaluation of emissions from mineral wool processes include:

Method 1 - Sample and Velocity Traverses for Stationary Sources

Method 2 - Determination of Stack Gas Velocity and Volumetric Flow Rate

Method 5 - Determination of Particulate Emissions from Stationary Sources

Method 6 - Determination of Sulfur Dioxide Emissions from Stationary Sources

Method 7 - Determination of Nitrogen Oxide Emissions from Stationary Sources

Method 8 - Determination of Sulfuric Acid Mist and Sulfur Dioxide Emissions from Stationary Sources

Method 9 - Visual Determination of the Opacity of Emissions from Stationary Sources

TABLE 7-1. AVAILABILITY OF EMISSION TEST RESULTS

ALABAMA - DEPARTMENT OF HEALTH, JEFFERSON COUNTY

Plant Name and City	Date	Process Source	Control Equipment	Sample Point	Pollutant(s) Sampled	Method	Data Received
U. S. Gypsum Birmingham, AL	2/74 and 3/74	Cupola	Multiple cyclones	Control device outlet	Particulates	EPA-5	Summary and data sheets
U. S. Gypsum Birmingham, AL	4/74	Cupola	Multiple cyclones	Control device outlet	Particulates	EPA-5	Summary and data sheets
U. S. Gypsum Birmingham, AL	8/74	Cupola	Multiple cylcones	Control device outlet	Particulates	EPA-5	Summary and data sheets
U. S. Gypsum Birmingham, AL	3/76	Blowchamber	Spray chamber	Control device outlet	Particulates	EPA-5	Summary and data sheets
U. S. Gypsum Birmingham, AL	11/77	Curing Oven	ESP	Control device outlet	Particulates	EPA-5	Summary and data sheets
Rockwool Industries Leeds, AL	11/78	Cupola	Baghouse	Control device outlet	Particulates	EPA-5	Summary and data sheets
Rockwool Industries Leeds, AL	11/78	Blowchamber	Wet Scrubber	Control device outlet	Particulates	EPA-5	Summary and data sheets

CALIFORNIA - SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT, COLTON, CALIFORNIA

Rockwool Industries Fontana, CA	10/70	Cupola	Wet Scrubber	Control device outlet	Particulates NO_x CO	Not specified Not specified Not specified	Summary only
Rockwool Industries Fontana, CA	10/70	Batt line	Wet Scrubber	Control device outlet	Particulates NO_x CO	Not specified Not specified Not specified	Summary only
Rockwool Industries Fontana, CA	10/70	Blown wool room	Wet Cyclone	Control device outlet	Particulates NO_x	Not specified Not specified	Summary only

CALIFORNIA - SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT, COLTON, CALIFORNIA (Continued)

Plant Name and City	Date	Process Source	Control Equipment	Sample Point	Pollutant(s) Sampled	Method	Data Received
Rockwool Industries Fontana, CA	2/71	Cupola	Wet Scrubber	Control device outlet	Particle size distribution Fluorides	Andersen sampler Not specified	Summary only
Rockwool Industries Fontana, CA	11/72	Cupola	Pilot Baghouse	Control device inlet and outlet	Particulates SO_2	Not specified Electrochemical cell continuous measurement	Summary only
Rockwool Industries Fontana, CA	2/74	Cupola	Baghouse	Control device outlet	Particulates SO_2 CO	Not specified Not specified Not specified	Summary only
Rockwool Industries Fontana, CA	4/74	Cupola	Baghouse	Control device outlet	CO NO_x	Gas chromatography Phenoldisulfonic acid	Summary only
Rockwool Industries Fontana, CA	6/74	Cupola	Baghouse	Control device outlet	Particulates	EPA-5 and APCD	Summary only
Rockwool Industries Fontana, CA	4/76	Cupola	Baghouse	Control device outlet	Particulates SO_2 NO_x CO	Unknown APCD APCD Unknown	Summary only
Rockwool Industries Fontana, CA	8/77	Cupola	Baghouse	Control device inlet	Particulates SO_2 CO NO_x Hydrocarbons	Not specified Not specified Not specified Not specified Not specified	Summary only
Rockwool Industries Fontana, CA	12/77	Batt room	None	Room exhaust	Particulates	Not specified	Summary only
Rockwool Industries Fontana, CA	12/77	Blow room	None	Room exhaust	Particulates	Not specified	Summary only
Rockwool Industries Fontana, CA	6/79	Cupola	Baghouse + CO Control System	Outlet from control devices	CO	Gas chromatography	Summary only

INDIANA - AIR POLLUTION CONTROL BOARD, STATE OF INDIANA

Plant Name and City	Date	Process Source	Control Equipment	Sample Point	Pollutant(s) Sampled	Method	Data Received
Rockwool Industries Alexandria, IN	10/72	Cupola	None	Cupola exhaust	Particulates SO_2 NO_x Fluorides	ASME-PTC27 Los Angeles Phenoldisulfonic acid Los Angeles	Summary only
Celotex Corporation Lagro, IN	6/74	Cupola	Multiple cyclones	Control device outlet	Particulates	Not specified	Summary only
U. S. Gypsum Wabash, IN	12/74	Cupola	Multiple cyclones	Control device outlet	Particulates	Not specified	Summary only
Johns-Manville Alexandria, IN	8/71	Cupola	None	Cupola exhaust	Particulates SO Fluorides	ASME PTC-27 Los Angeles Los Angeles	Summary and data sheets

MISSOURI DEPARTMENT OF NATURAL RESOURCES, JEFFERSON CITY

Rockwool Industries Cameron, MO	5/78	Cupola	Baghouse	Control device outlet	Particulates	Not specified	Summary only

8. STATE AND LOCAL EMISSION REGULATIONS

The following section summarizes the emission regulations concerning newly constructed mineral wool manufacturing plants. Only the regulations of the 14 States where mineral wool is currently manufactured were examined. It is believed that these 14 States are representative of the emission standards for all 50 States. These regulations were primarily taken from the Environment Reporter[1] with supplemental information gathered from State and local air pollution control agencies.

Emission regulations are presented and compared in Table 8-1. In order to compare the various State regulations, it was necessary to choose process weight rates and exhaust gas flow rates for a typical plant. A typical plant was assumed to have the following parameters:

Cupolas:
- charging rate - 3 T/hr
- exhaust gas temperature - 300°F
- exhaust gas flow rate - 6600 scfm (9650 acfm at 300°F)

Blowchambers:
- process weight rate - 1.8 T/hr
- exhaust gas temperature - 180°F
- exhaust gas flow rate - 20,000 scfm (24,800 acfm at 180°F)

Curing Ovens:
- process weight rate - 1.8 T/hr
- exhaust gas temperature - 320°F
- exhaust gas flow rate - 5000 scfm (7500 acfm at 320°F)

Table 8-1. Summary of Particulate Emission Regulations for New Mineral Wool Manufacturing Processes

State	Number of Plants	General Process Regulation[a]	Allowable Particulate Emissions: Cupola Kg/h	Cupola lb/hr	Blowchamber Kg/h	Blowchamber lb/hr	Curing Oven Kg/h	Curing Oven lb/hr	Visible Emissions Percent Opacity
Alabama	3	Class I county: $E = 3.59\ P^{0.62}$	3.22	7.09	2.35	5.17	2.35	5.17	20
		Class II county: $E = 4.1\ P^{0.67}$	3.89	8.56	2.76	6.08	2.76	6.08	
California	1	b	b		b		b		b
Colorado	1	$E = 3.59\ P^{0.62}$	3.22	7.09	2.35	5.17	2.35	5.17	20
Illinois	1	$E = 2.54\ P^{0.534}$	2.08	4.57	1.58	3.48	1.58	3.48	30
Indiana	6	$E = 4.1\ P^{0.67}$	3.89	8.56	2.76	6.08	2.76	6.08	40
Minnesota	2	$E = 3.59\ P^{0.62}$	3.22	7.09	2.35	5.17	2.35	5.17	20
Missouri	2	$E = 4.1\ P^{0.67}$	3.89	8.56	2.76	6.08	2.76	6.08	20
New Jersey	1	99% removal of uncontrolled particulates (removal not required below 0.02 gr/scf)	0.51	1.13[c]	1.56	3.43[c]	0.39	0.86[c]	20
North Carolina	1	$E = 4.1\ P^{0.67}$	3.89	8.56	2.76	6.08	2.76	6.08	20
Ohio	1	$E = 4.1\ P^{0.67}$	3.89	8.56	2.76	6.08	2.76	6.08	20
Pennsylvania	3	0.04 gr/scf	1.03	2.26	3.12	6.86	0.78	1.71	20
Tennessee	1	$E = 3.59\ P^{0.62}$	3.22	7.09	2.35	5.17	2.35	5.17	20
Texas	3	BEST AVAILABLE CONTROL TECHNOLOGY							20
Washington	1	0.1 gr/scf	2.57	5.66	7.79	17.14	1.95	4.29	20

[a] E = allowable emissions (lb/hr)
P = Process weight rate (tons/hr)
Q = Actual exhaust gas flow (acfm)
gr/scf = Allowable concentration of particulate matter in grains per standard cubic foot of exhaust gas

[b] Regulation is by county or air pollution control district. For the South Coast district, no new plant can emit more than 250 lbs/day of any pollutant and opacity is limited to 20 percent.

[c] Based on 0.02 gr/scf

In making this comparison, it was assumed that each State considers a production line containing a cupola, blowchamber, and curing oven to consist of three separate processes. It was also assumed that the process weight rate was determined on a once-through basis (no increase in allowable emissions could be achieved by returning the airlift exhaust to the blowchamber so that the throughput could be counted twice in determining the process weight rate).

In general, the only pollutant emitted from mineral wool processes which is subject to regulation in every State is particulate matter. The State of Pennsylvania requires the installation of afterburners on all mineral wool curing ovens to control odors. Several States require afterburners to control carbon monoxide emissions from grey iron foundry cupolas, but mineral wool cupolas are not included in these regulations.

A typical mineral wool plant has two parallel production lines with only one line having a curing oven. Taking $E = 3.59p^{0.62}$ to represent an average State general process emission regulation, this typical plant could emit allowable particulate emissions totalling about 30 lbs/hr from the 5 emission sources operating at process rates previously stated.

Of those examined, the most stringent emission regulation was that of the South Coast Air Quality Management District of California. Under these regulations, no new mineral wool plant could be built which would emit more than a sum of 250 lbs/day of any pollutant from all emission sources at the facility.

REFERENCES

1. Environment Reporter. Bureau of National Affairs, Inc., Washington, D. C.